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MECHANICAL ENGINEERING

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H. F. Shepherd

F. Van Deventer

D. L. Bruner

H. R. Harris

W. G. Wohlenberg

B. Bannister

R. T. Kent

Contributors to this Issue

William LeRoy Emmet, author of The Emmet Mercury-Vapor Process, has achieved fame as an electrical engineer and as an inventor. Mr. Emmet was graduated from the U. S. Naval Academy in 1881. During the Spanish-American War he served as a navigator on the U. S. S. *Justin*. His principal engineering connections have been those with the Sprague Electric Railway & Motor Co. and the General Electric Co. His most important electrical work has been in the development of the general use of alternating currents, while his best-known mechanical activities have been those concerned with the development and introduction of the steam turbine. He received the degree of D.Sc. from Union College in 1910. He was awarded the gold medal for vertical-shaft turbine at the St. Louis Exposition, the gold medal for electric ship propulsion at the San Francisco Exposition, the Edison Medal in 1919, and the Elliott-Cresson Medal in 1920.

W. L. R. Emmet

* * * * *

H. F. Shepherd, consulting engineer with the Foos Gas Engine Co., Springfield, Ohio, is the author of the paper on The Solid-Injection Oil Engine. After eight years of preliminary training he entered the employ of the Bessemer Gas Engine Co. as a draftsman, eventually becoming engineer in charge of their oil-engine division. During ten years his service with this company was broken twice first by a short engagement with the De La Vergne Machine Co., and later by a period of study in England on high-pressure-engine design. For the past two years Mr. Shepherd has been engaged in research on all types of oil engines.

* * * * *

Bryant Bannister, and **F. M. Van Deventer** are co-authors of the paper in this issue on Power Organization in the Steel Industry. Mr. Bannister was graduated from the University of Illinois in 1911 and then took a post-graduate course at Massachusetts Institute of Technology. He has been associated with the National Tube Co. since 1910, first as superintendent of power at the Kewanee Works, and since 1912 as power engineer in the general office of that company in Pittsburgh.

Mr. Van Deventer was educated at the University of Illinois, receiving a B.S. degree in 1917 and an M.E. in 1922. From 1916 to 1918 he was assistant operating engineer for the Illinois Traction System. Since that time he has been associated with the National Tube Co. as mechanical engineer in the power department.

* * * * *

W. J. Wohlenberg, who writes on Reheating in Central Stations, was born in Lincoln, Neb. He was graduated from the University of Nebraska in 1910. He spent two years in engineering research work at the University of Illinois and similar periods as assistant professor of mechanical engineering at the University of Oklahoma and later at the University of Montana. Since 1918 he has been assistant professor of mechanical engineering at Yale University.

* * * * *

E. J. Armstrong, assistant engineer of plant of the William Cramp & Sons Ship & Engine Building Co., Philadelphia, Pa., writes on Machining Massive Parts of the World's Largest Prime Movers. Previous to 1908 when Mr. Armstrong entered the employ of the Cramp Co., he was connected with Bement, Miles & Co., the Neafie & Levy Ship & Engine Building Co., and the Midvale Steel Co. He is particularly qualified to write on this subject in view of the fact that during the war period many special tools were designed and built in the company's shops and it was often necessary to resort to special methods for machining the large parts such as are described in the paper.

* * * * *

Capt. H. W. Churchill, whose paper on Some Production Problems in the War Department's Preparedness Program appears in this issue, is executive assistant to the New York District Chief of Ordnance. Educated at Massachusetts Institute of Technology, he was executive engineer and production manager with the Burke Electric Co., Erie, Pa., before entering the Army. Soon after the outbreak of the war he was assigned to the Inspection Division and stationed in the Detroit Ordnance District. He has since served on the Salvage Board and the War Department Claims Board in Washington.

* * * * *

Robert T. Kent, author of The Mechanical Engineering of Management in the Metal-Working Trades, was graduated from Stevens Institute of Technology in 1902. He was associated for a time with the Link-Belt Co. of Philadelphia and was for four years engineering editor of the *Iron Trade Review*. Since 1912 he has engaged in consulting work in the shop-practice and management fields. At the outbreak of the war Mr. Kent was appointed chief engineer of Meyer, Morrison & Co., consulting engineers, and in this connection supervised the organization and production of some of the largest metal-working plants in the United States.

* * * * *

Harold R. Harris and **Donald L. Bruner** are co-authors of the article on Night-Flying Equipment and Operation, and first lieutenants in the Air Service of the U. S. Army. Lieutenant Harris was graduated from the California Institute of Technology and also from the Air Service Engineering School. He entered the Air Service in 1917 and was officer in charge of flying instructions of the 8th Aviation Instruction Center, Foggia, Italy. He was in command of the first American flight across the Alps in 1918. For three years he has been chief of the Flying Section, Engineering Division of the Air Service. He holds the decoration of the Order of the Crown of Italy from the Italian Government.

Lieutenant Brunner is a graduate of Iowa State College and before the war was designing engineer with the General Electric Co. He entered the Air Service in 1917, attending the Ground School at Cornell University, the Primary Flying School at Kelly Field, the Aeronautical Engineering School at M.I.T., and the Air Service Engineering School at Dayton, Ohio. At present he is officer in charge of electrical and night-flying equipment, Engineering Division, Air Service.

MECHANICAL ENGINEERING

Volume 46 May, 1924 No. 5

The Emmet Mercury-Vapor Process

Early Experiments—Thermodynamic Possibilities of the Process—The Hartford Installation—Boiler Problems—Mercury Turbines—Packings and Leakage— Economies Attainable—The Mercury Supply

By W. L. R. EMMET,[1] SCHENECTADY, N. Y.

IN THIS PROCESS mercury is vaporized in a boiler at temperatures which can be much higher than those which are practicable with steam. It is then carried through a turbine and does useful work, exhausting into a surface condenser where its latent heat is used to make steam at pressures desirable for use. The condensed liquid is carried back to the boiler preferably by gravity. The characteristics of mercury are such that high temperature can be used without excessive pressure, and the heat of condensation can be delivered at a convenient degree of vacuum and at a temperature suited to making steam at pressures desirable for power uses. The process thus affords means by which the temperature ranges practicable with steam are greatly increased under conditions which afford large gains in efficiency of conversion of the heat energy of fuel into work.

History of the Process

The possibilities of this process were first explained in a paper presented by the author at a meeting of the American Institute of Electrical Engineers in 1913. The possible uses of the principle involved were, as there stated, suggested to him by Chas. N. Bradley, who has done much original work in many fields. He did not propose the use of mercury for such a purpose, but thought that some other substance could be found with suitable qualities and a sufficiently high boiling point. Mr. Bradley had taken out a patent involving the general principle of such an application. There had also been one or two others who had previously proposed binary-vapor processes which suggested the use of other substances in temperature ranges higher than those to which steam was well adapted.

As a result of these suggestions the author began an effort to find some substance which might have qualities suited to the accomplishment of this very attractive object, and, through various circumstances, finally came to the conclusion that mercury, in spite of its high cost, poisonous quality, and tendency to oxidation, might by sufficient care and study be applied to this purpose.

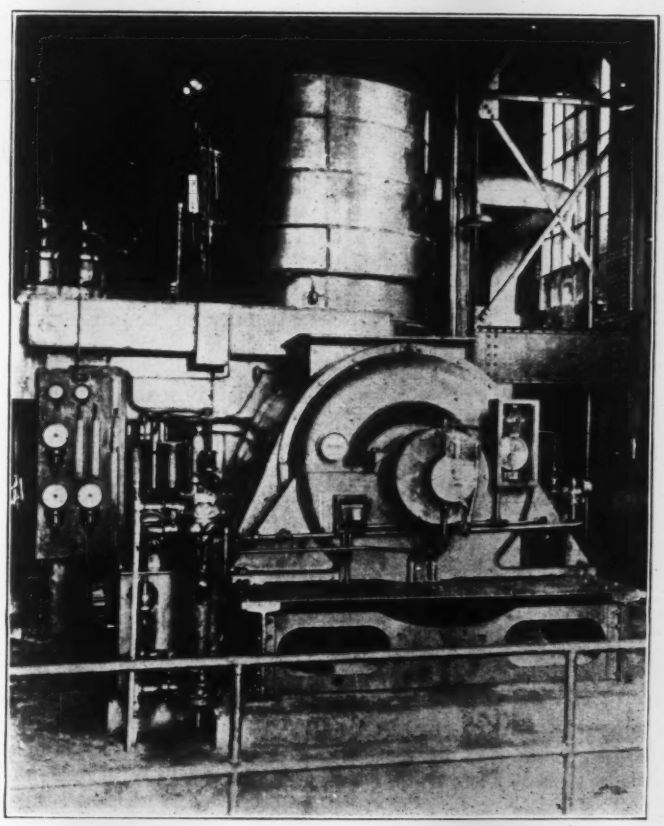


Fig. 1 View of Mercury Condenser, Turbine, and Generator, Hartford Electric Light Co., Hartford, Conn.

Experiments

A campaign of experimentation was then begun, of which the earlier steps are described in the paper above mentioned. The first steps in this experimentation developed few difficulties, although much time was expended in building operations, and as a result of these apparent successes a large equipment designed to deliver 1500 kw. from the mercury turbine was built for installation in the power station of the General Electric Company at Schenectady.

Work on this equipment was begun in 1915, and after more than two years of discouraging delays in building operations it was put in operation. A variety of practical difficulties were encountered and a long time passed before it could be run under load. The long succession of delays, difficulties, and disappointments in connection with this installation need not be described now. Their nature for the most part was such as not to discredit the idea, and many of the most important features were entirely successful. The equipment was ultimately run on a number of occasions with loads as high as 1000 kw., and, while the efficiency of the one-wheel turbine was only about 60 per cent, the results clearly showed that the economies claimed for the process could be realized and that the knowledge developed by calculation and experiment was substantially correct. While the building, changing, and handling of this apparatus involved much loss of time and much worry and discouragement, it afforded practical experience without which such a new and complicated development could hardly be expected to advance.

The outstanding lesson of this venture was that more must be learned about the principles involved in the construction of a good mercury boiler, and experiments with that end in view have been going on on a considerable scale ever since. In making boiler experiments which are to be depended upon we cannot work on too small a scale, since we must create conditions of fire temperature and radiant-heat delivery similar to those in actual boilers.

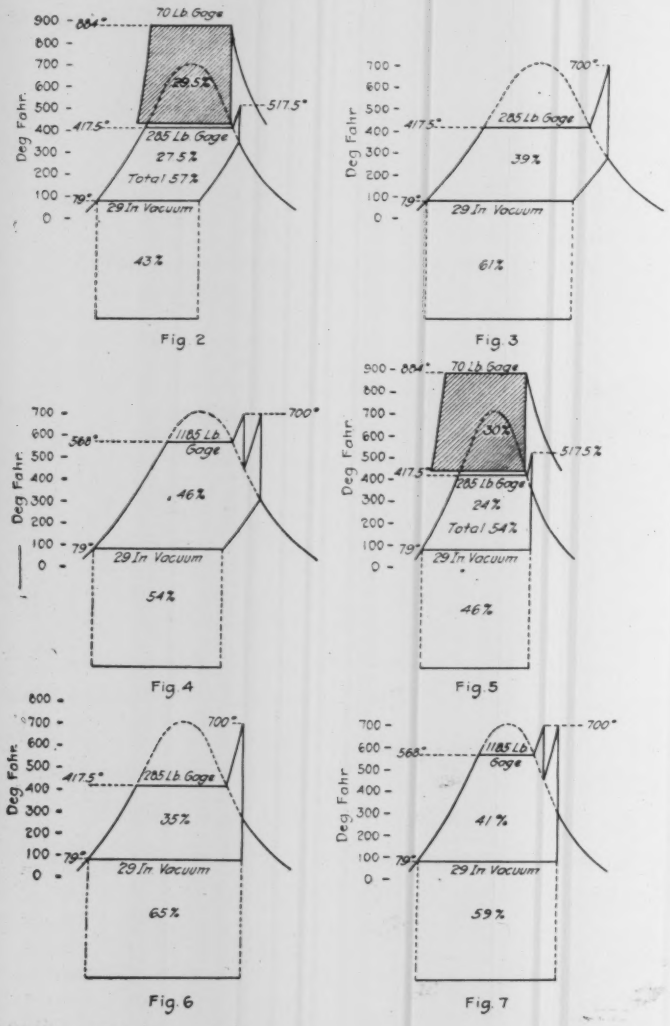
The boiling conditions of mercury are peculiar and very different from those of water. The metal does not wet the surfaces and there is a wide difference of pressures at different depths. Theories concerning the action have been formed and tested by circulating mercury with compressed air in glass structures, by boiling it in single

[1] Consulting Engineer, General Electric Co. Mem. A.S.M.E.

Contributed by the Power Division for presentation at the Spring Meeting, Cleveland, Ohio, May 26 to 29, 1924, of The American Society of Mechanical Engineers. All papers are subject to revision.

tubes of various shapes, with measurements of vapor production, liquid circulation, and temperature determination. Several types of boilers of workable size have been built and tested.

When these experiments and studies had given a type of boiler which promised reliability in actual service it was decided to begin work on another large equipment, and it was thought wise to put it in an operating plant, if one could be found to receive it, instead of installing it in Schenectady. About this time the Hartford (Conn.) Electric Light Company made a voluntary offer to the author to make such an installation, and this has been done in their



FIGS. 2–7 DIAGRAMS ILLUSTRATING THE THEORETICAL POSSIBILITIES OF THE MERCURY-VAPOR PROCESS

Dutch Point Plant. Their enterprise and foresight have done much toward bringing the process to its present advanced state.

THERMODYNAMIC POSSIBILITIES OF THE PROCESS

Before going into the details of the apparatus which has been built and the results which have been accomplished, it may be well to consider the theoretical possibilities as compared with steam processes. An appendix[1] to this paper contains a mercury steam table prepared by Mr. L. A. Sheldon, who has assisted the author since the beginning of work on this process. With this table are given the authorities for the data employed and the calculations. The degree of accuracy of the figures presented is not known, but experience with nozzle flows and turbine results has indicated that they are nearly correct.

[1] This appendix, which it is intended to publish later, includes a table of the properties of mercury vapor at absolute pressures ranging from 0.4 to 180 lb. per sq. in., a Mollier chart for mercury, and a chart showing the available energy of mercury vapor in watt-hours per lb. for expansions from absolute pressures of from 20 to 85 lb. per sq. in. to back pressures of from 0.4 to 1.6 lb. abs.

In this process the mercury is boiled, carried through a turbine and condensed, giving up its vapor heat to the making of steam. The boiling might theoretically be accomplished at any practicable temperature and pressure, and experience has indicated the temperatures much higher than that here considered may be practicable. The condensation of the mercury and the making of the steam can also occur at any point in the descending temperature scale which gives a practicable mercury vacuum. The final termination of the steam action must be at the temperature of the cooling source, namely, that of the condensing water.

For purposes of illustration we will assume a boiling temperature of 884 deg. fahr., corresponding to a pressure of 70 lb. gage in the mercury boiler. As a temperature for condensing mercury we will assume 438 deg. fahr., corresponding to a mercury vacuum of 28.5 in. and being suited with a temperature difference in the condenser of 21 deg. fahr. to the making of steam at 285 lb. gage pressure. The lower limit of steam use is taken at 79 deg. fahr., corresponding to a 29-in. vacuum.

The using of a higher mercury vacuum and a lower steam pressure might be expected to give better efficiency, but 28.5 in. is a suitable vacuum for the most convenient design of the mercury turbine.

The accompanying diagrams, Figs. 2 to 7, show relative areas of work and loss and are based upon the entropies of the fluids. They illustrate the theoretical possibilities. The vertical dimensions of these diagrams represent temperature differences. The areas above the line corresponding to 79 deg. fahr., 29 in. vacuum, are proportionate to the work theoretically available. Those below this line are proportionate to the heat energy carried away by the condensing water.

Fig. 2 shows the mercury-steam cycle with mercury vaporized at 70 lb. gage, steam made at 285 lb. gage, superheated 100 deg. and expanded by what is known as the Rankine cycle—that is, without heating the feedwater by steam which has been partly expanded and used to give work. In Figs. 2, 3, and 4 this Rankine cycle is shown. In Figs. 5, 6 and 7 a cycle is shown in which the theoretical maximum of feed heating is assumed through extraction of steam from the prime mover at all points in the descending scale of temperature.

The 100 deg. of steam superheat in Fig. 2 is that which can be conveniently made after as much heat as easily possible has been delivered from the furnace gases to the making of mercury vapor. The relative expediency of putting added heat from fuel into steam superheat or into more mercury vapor depends upon the relative efficiencies of the mercury and steam turbines and upon the gain by superheating in the steam turbine. With good steam turbines and such mercury turbines as will probably be available there should be some gain in using a higher superheat in the steam, which is easily got by reducing the surface of the mercury heater and increasing that of the superheater.

Heating the feedwater by extracted steam will materially improve this process as it does the steam alone, but naturally not so much relatively since the steam alone is affected. As in steam cycles the benefit of full feed heating by extracted steam will be greater with higher steam pressures, but, while under such conditions there will be a gain in efficiency by using higher steam pressures with the mercury, this gain will not be large and moderate steam pressures will generally be considered desirable. The gap in the work diagrams, Figs. 2 and 5, corresponds to the temperature difference in the condenser.

In all the diagrams the total areas are the same, representing equal heat energy delivered from the fuel, and the proportions of areas representing work available and heat energy rejected to condenser are given by percentages which show the theoretical efficiency.

Fig. 3 shows steam at 285 lb. gage, superheated to 700 deg. fahr. and expanded to a 29-in. vacuum.

Fig. 4 shows steam at 1185 lb. gage and superheated to 700 deg. fahr., expanded until it loses its superheat, then reheated again to 700 deg. fahr. and expanded to a 29-in. vacuum.

Figs. 5, 6 and 7 show the same as Figs. 2, 3 and 4, except that the theoretical maximum of feed heating is assumed by steam extraction after the steam finally reaches saturation.

Since perfect efficiency of apparatus is impossible—and for many

other reasons—none of these conditions can in practice be accomplished and many variations of the conditions might be made. The diagrams, however, serve to illustrate the principle and are useful for purposes of comparison.

THE HARTFORD INSTALLATION

The equipment at Hartford was designed to operate with 35 lb. gage pressure on the mercury boiler, to deliver about 1800 kw. from the mercury turbine, and to make steam at 200 lb. pressure with about 100 deg. of superheat. The character of the apparatus can best be observed from the drawings and photographs reproduced

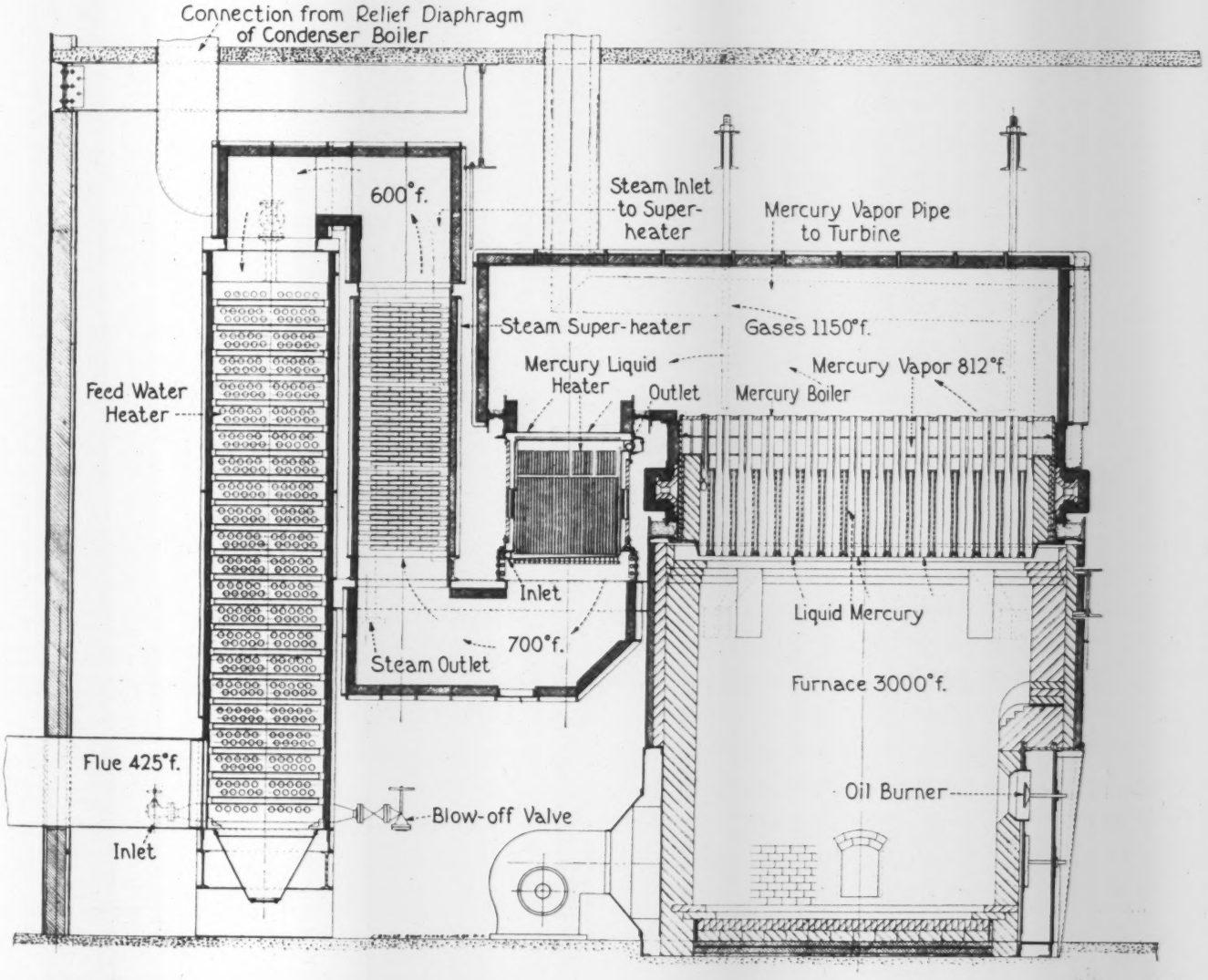


FIG. 8 SECTION THROUGH MERCURY BOILER, HEATER, SUPERHEATER, AND FEEDWATER HEATER

in Figs. 8–13. The furnace gases pass in order through the mercury boiler, a mercury-liquid heater, a steam superheater, and a feedwater heater. It would be more economical to substitute for the last-named device an air heater, since it would put this residuum of heat into the mercury instead of into the steam. The feed heating would then be accomplished by bleeding the steam turbine. The approximate temperatures in the gases at different points, and the temperatures and pressures of fluids, are given in Figs. 8 and 9.

Referring to Fig. 9, the mercury vapor formed in the boiler passes through a governing and emergency valve to the turbine, the single wheel of which is overhung on the end of the generator shaft and operates in the condenser space. Two safety valves are arranged to bypass the vapor into the condenser if the governor causes its valve to close, so that the mercury vapor continues to be condensed and to make steam whether it is passing through the mercury turbine or not. The shaft passes through a packing between the generator and the turbine wheel and this is sealed by mercury vapor above atmospheric pressure. The outward leakage from this packing is sucked into a cooler where it is all condensed and returned to the system.

The discharge from the turbine wheel is delivered directly against the condensing surface which consists of dead-ended tubes hanging vertically from a cylindrical steam and water drum, to which they are attached by rolling and also by arc welding.

The condenser shell and all the pipes and containers which carry mercury are put together by welding. From the condenser the liquefied mercury runs through a sump to the mercury heater and boiler by gravity.

On the side of the condenser shell a large blowout diaphragm is provided which communicates to the stack and will give way if, through escape of steam or water or other cause, the pressure in the condenser should begin to rise unduly.

The mercury boiler at Hartford is made up of fire tubes the lower two-thirds of which are hexagonal with slightly convex faces. These are nested together like a honeycomb (Fig. 10), and for each 7 tubes a space is left for a duct which returns the circulating liquid. This liquid rises and the vapor forms in clearances between the tubes at the corners. The use of such tubes in a mercury boiler was proposed by Mr. B. P. Coulson, the author's assistant. The upper round part of the tubes acts as superheating surface and the vapor is delivered with a little superheat, which is desirable for the reason that it probably tends to prevent cutting of the turbine blades—of which there has been none

at Hartford, although a slight amount was observed in former turbines.

This equipment has been run experimentally for several months. Few troubles have been experienced and nothing of a serious nature. It has delivered power to the circuits for about 800 hours. The highest load carried has been 1500 kw. and the load carried most of the time has been 1200 kw. There has been some uncertainty as to the safe capacity of the boiler and, since experience with continued operation has been the most important need, it has been thought best to avoid risk of any possible serious trouble. The conditions of running cannot be considered commercial, but the independently. These tubes are arranged in such a manner that they receive radiant heat from below, the gases passing upward in rather small and converging spaces between them. The arrangement is such that all tubes receive nearly equal quantities of heat both from radiation and from contact with the gases. A section of such a boiler is shown in Fig. 11. Twenty of these sections would be used with a 7500-kw. mercury-turbine unit, boilers in a number of sections operating in parallel and any section being removable for cleaning or repair if necessary.

This type of boiler has the advantage that its heating surface is free from expansion strains. It also makes possible the calorizing

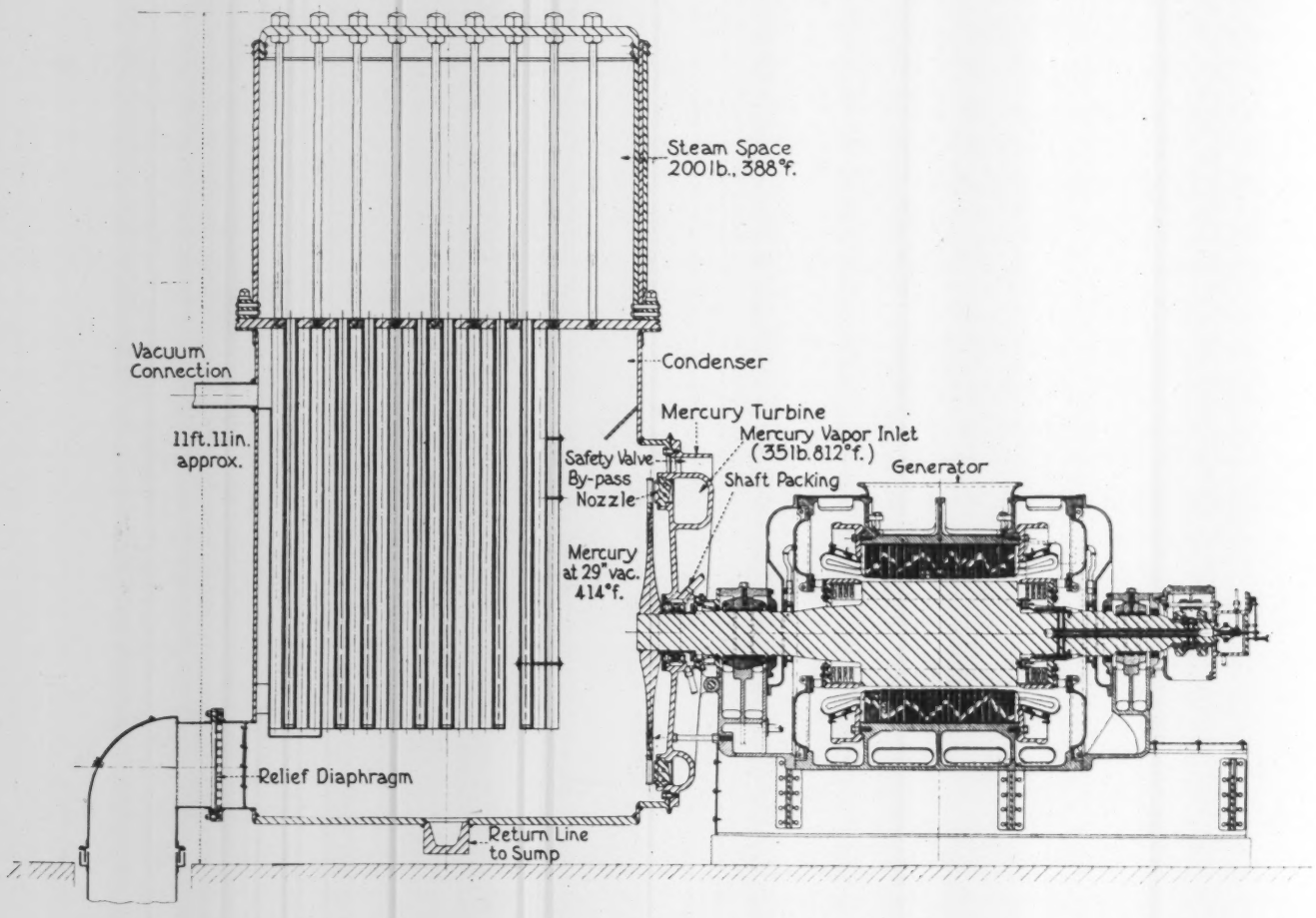


FIG. 9 SECTION THROUGH MERCURY CONDENSER, TURBINE, AND GENERATOR

results secured give a very good indication that commercial results are not difficult of attainment.

BOILER PROBLEMS

The most difficult and novel part of this process is the boiler. While mercury is a good heat conductor, it does not wet steel and considerable temperature differences are required to deliver heat to it at a high rate. When it begins to produce vapor on the heating surfaces this condition becomes rapidly worse. Successful mercury boilers are dependent upon a rapid circulation of the liquid and the large difference of pressure between the top and the bottom which prevents boiling of the circulating liquid until it is well started on its upward course. That is, the rapid heat delivery must be confined to the part of the surface which is not much disturbed by boiling. Rapid circulation is essential and the spaces for discharging vapor must be so proportioned that the circulation will not be checked by the escape of the vapor. If these spaces are too small the liquid will be given motion like a charge of shot, and prohibitive back pressure will result which will check circulation. The vapor must slip by the liquid, impelling it but not giving it too much velocity.

In the type of boiler which is now considered most promising these functions are accomplished in dead-ended tubes with interior structures which provide the circulation conditions for each tube of the tubes. This process, which was developed in the General Electric Research Laboratory, aluminizes the surface of the tubes so that they are immune from burning at high temperatures. It is used successfully in petroleum stills at temperatures much higher than those which need concern us in the mercury process. Such treatment will render possible the use of higher pressures in the process, since the pressures already employed approach the point at which iron begins to scale destructively. Higher pressures will afford better economy, and there seems to be nothing against their use outside of the boiler. The turbine is of low speed and there are no heavy centrifugal strains as in steam turbines.

OXIDE AND IMPURITIES

Mercury does not oxidize very rapidly even when exposed to air at high temperatures, but a small degree of oxidation seems to render the metal adhesive and makes it very difficult to separate finely divided foreign matter. Experience has shown that if the scum formed by oxidation accompanied by scale, dirt, cuttings from the steel, etc., is allowed to freely form and circulate in a mercury-boiler system, accumulations are likely to occur in interior passages, and that in these accumulations large crystals of red oxide are likely to form, increasing the bulk of solids and causing danger of stoppages. For these reasons it has been found desirable to carefully protect the mercury from frequent or continued ex-

posure to oxygen, and this has been done by filling the boiler and condenser with illuminating gas when they are shut down. Arrangements have also been made by which gas is kept in the cleaning sump and can be kept in contact with the mercury which leaks from the packing, although this small quantity could be cleaned continuously as it returns to the system if desirable. Hydrogen and carbonic oxide are reducing agents for mercury and, working with them, the liquid is not adhesive and cleaning is relatively easy.

Expansion Strains

In such apparatus the temperature differences are very large and expansion strains must be scrupulously guarded against. The problem is similar to that in properly designed steam apparatus, but much more important because leaks are prohibitive and any repeated excess strain will make a crack. In all welded joints the weld should be made much stronger than the metal adjacent to it; otherwise small movements may concentrate there and develop cracks.

Mercury Turbines

In the first ventures which have been made in mercury turbines, single wheels of the impulse type, like the original DeLaval turbines, have been used. This was done for the sake of simplicity, the speed conditions being suited to such a wheel. It was not known how much the mercury might wear the blades. Mercury discharged at high velocity and high temperature does cut ordinary steel rapidly.

It has been found, however, that tempered high-speed tool steel is hardly at all affected under the severest conditions. The Hartford turbine was fitted with buckets of this metal and some of soft steel. Neither has been even slightly affected, and the inference is that a turbine with a plurality of stages and buckets of ordinary steel can be used. It may be that it will be found desirable to use special buckets in the higher stages where the temperature is higher. The Hartford turbine has a hooked-on bucket construction by which the wheel can be quickly rebucketed by a man working inside of the condenser.

In many respects the problems of mercury turbines are similar to those of steam turbines. The velocities involved, however, are of the order of one-third and the mechanical problems are therefore much easier notwithstanding the high temperature. The single-wheel turbine at Hartford will in a short time be replaced by a three-wheel machine, also overhung inside the same condenser. It is hoped that this will give a fair efficiency and good durability.

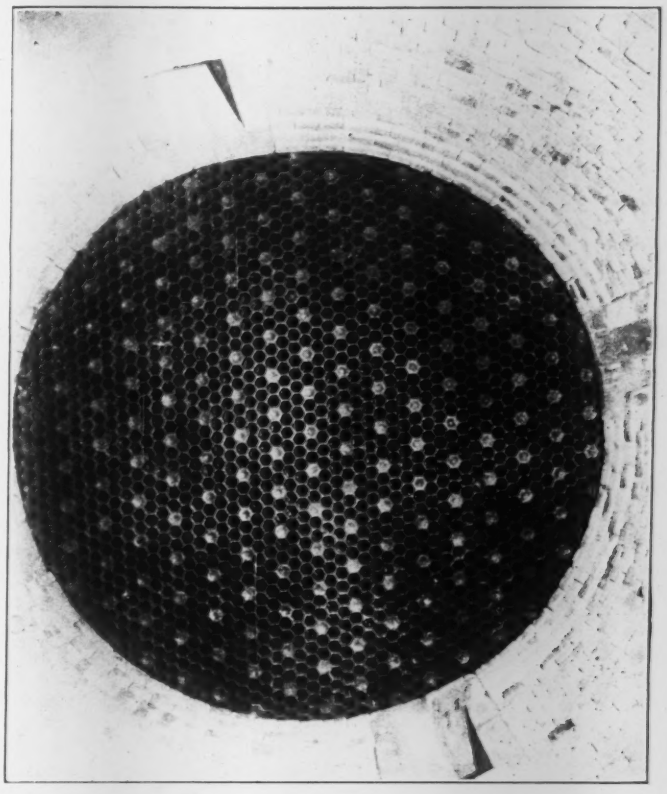


FIG. 10 BOTTOM OF MERCURY BOILER SET IN FURNACE, HARTFORD INSTALLATION

Packings

Two types of shaft packings have been successfully used in mercury turbines, in one case the seal being centrifugal with liquid mercury, and in the other being made with mercury vapor. The latter type has been found most convenient. Since the conditions are peculiar and it is not expedient to use split or jointed structures, it has been found desirable to develop a special type of self-centering

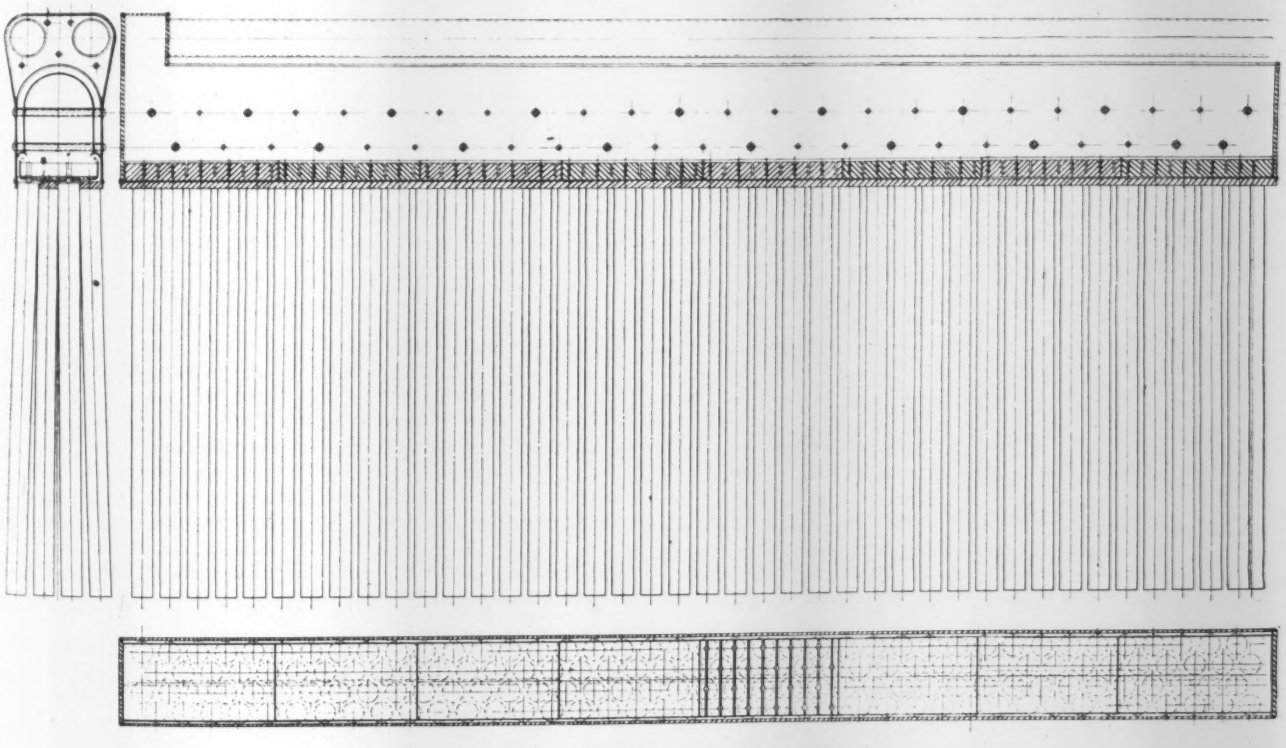


FIG. 11 NEW TYPE OF BOILER UNIT WITH CLOSED-END TUBES

packing ring. In this a light cast-iron ring is riveted to, and held circular by, a deep ring flange of chrome steel, the whole being held in place frictionally by springs of a material suited to the high temperature.

CONDENSATION AND STEAM MAKING

The condensing conditions with mercury are peculiarly good. The liquid does not wet the surface and the falling drops tend to move the vapor and also to give added condensing surface. In

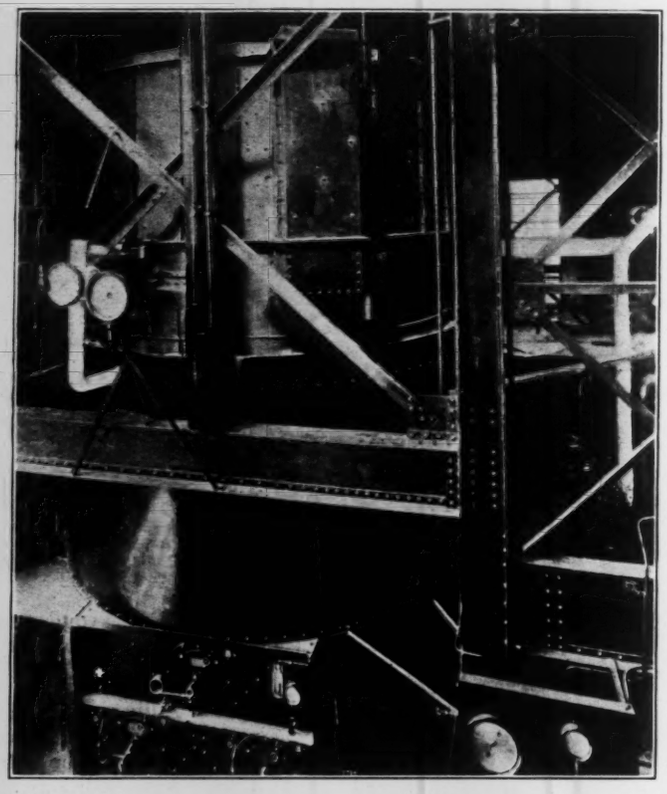


FIG. 12 MERCURY BOILER INSTALLED ON LOWER FLOOR AT HARTFORD

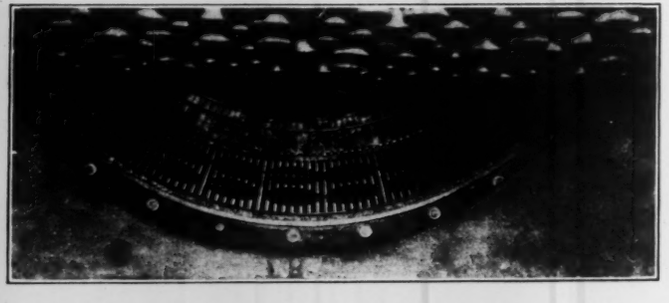


FIG. 13 VIEW OF TURBINE WHEEL AND CONDENSER-BOILER TUBES

Hartford we have run with 770 B.t.u. transfer per degree fahrenheit temperature difference per square foot per hour.

The limitation of heat delivery is probably governed largely by heat conduction through the heavy steel tubes, and delivery as indicated by the falling mercury, which has been observed through a lighted window, seems to be quite uniformly distributed over the condensing surface. This makes a very good condition for the production of steam. There can be no overheat or strain, and scaling can only result ultimately in impairment of the mercury vacuum. The steam space can be made very large without inconvenience or appreciable added expense.

The tubes are accessible from above through handholes at the top of the drum, and can be cleaned by inserting into the top of the tube a nozzle connected to a piece of flexible pipe or hose. Through this another small hose can be run down to the bottom of the tube, and scale or dirt can be flowed out with water after it has been loosened by the ordinary means.

METHOD OF OPERATION

The arrangement of valves, the governing devices, etc., devised for this system are quite new and have proved to be very practical and successful, but their details cannot be described within the limits of the present paper. Since it is economical to use the mercury turbine as much as possible, the normal governing is done on the steam end and the governor of mercury turbine operates only as a speed-limiting device, being set to operate above the running speed fixed by the steam-turbine governors.

The furnace is operated and pressure and level in the steam part are held just as in the case of an ordinary steam boiler. If the mercury turbine cannot use the vapor made by the fire, it is bypassed through the safety valves. If the steam made cannot be used, the steam safety valves must blow as in any boiler. The mercury level in the boiler is indicated to the fireman by float gages, the motion of which is transmitted magnetically through disks of non-magnetic steel welded into the ends of the boiler sections when, as in the proposed design, the boiler is built in sections. If a loss of mercury should be observed, the temperatures should be checked as quickly as possible so that the loss may be reduced as much as possible.

LEAKAGE

The whole apparatus for this purpose has been developed with a view to avoiding the possibility of leaks, and experience with much experimental apparatus over a period of years has indicated that the desired results are not very difficult of attainment. With proper methods of welding and of proportioning of parts, leaks which may occur through imperfect work, imperfection of material, or expansion strains improperly provided for will generally be of the nature of minute cracks—and mercury leaks slowly on account of its low pressure and high density. Means have been developed by which the presence of a very small quantity of mercury in the flue gases can be shown by the discoloration of a strip of treated paper, so that inspection will show conditions. All parts of the apparatus will be readily accessible for repair if required. Most of the parts which carry mercury under pressure are in the flue-gas space, which, being subject to stack suction, cannot deliver fumes to the air which is breathed. The parts which are not so situated will be completely surrounded by sheet-metal enclosures outside the lagging, which spaces are also subject to stack suction.

POISONING

In ten years of experimentation with many kinds of mercury apparatus we have experienced no case of poisoning, but nevertheless realize that the utmost care is necessary. On several occasions men have been in contact with much mercury vapor in hot places, and in one or two cases men have been temporarily quite sick as an apparent result. There has been no case of salivation or continued symptoms of mercury poisoning, although most of these men have been on the job for long periods. The experience of mercury production and its use in other arts would indicate that, with reasonable precautions, the danger of poisoning should not be appreciable.

ECONOMIES

The most economical method of operating this process will generally be to get as much heat as possible into the feedwater by bleeding the steam turbine as in the best modern steam practice. Since such units will not be run at heavy overloads, as is common with steam boilers during peaks, it will be practicable to put a large quantity of heat into the incoming air without danger of burning the brickwork, and it is thought that such a device as the Ljungström air heater can be used to great advantage in bringing the flue gases to a low temperature and delivering their heat to the furnace. The heat from the furnace will be used to heat and vaporize mercury and to give such superheat to the steam as may be expedient with the steam apparatus used.

With such an arrangement, if we assume 70 per cent efficiency, 70 lb. pressure for the mercury cycle, and the most desirable steam conditions, we should be able to operate on base load for about 10,000 B.t.u. from fuel per kilowatt-hour.

(Continued on page 305)

The Production of Heavy Forgings

A Brief Survey of the Status of the Industry in America at the Present Time, Together with Data Helpful to the Engineer Ordering Forgings

THE production of forgings may be truly classed as one of key industries of the world. By means of forging, parts are produced which, with only a moderate amount of machining or grinding, can be given the desired shape and dimensions. Thus far the same purpose has been achieved by casting, with the difference, however, that hitherto no way has been devised to make castings of any but the simplest shapes thoroughly uniform in structure and reliable, and to attain in a casting the structure of metal that would enable it to withstand irregular and, particularly, repeated stresses. There are a number of conditions affecting grain formation in a casting such as lack of uniformity in cooling, production of cavities—either visible or microscopic and due to the contraction of the internal part of the casting after the solidification of the skin—segregation, separation of occluded gases, presence of sonims, etc., which make a casting at best a somewhat uncertain proposition and which usually produce in all castings, except those of certain simple forms, planes of weakness which may cause rupture under certain classes of strains, particularly those of a rapidly alternating character.

While a great advance has been made recently in the production of surprisingly strong castings due to the employment of electric furnace for melting and special methods of heat treating, it is nevertheless still a fact that castings as a rule are not sufficiently reliable for employment in members subjected to sudden and large stresses or the constant pounding and vibration which are so apt to break down what is known as the fiber of the metal. Experience has shown that in all such cases far better and more reliable results are obtained by the use of forgings, i.e., parts produced from ingots or partly rolled bars by reheating them to a proper temperature and submitting them to powerful mechanical action of a proper kind while at that temperature. The temperatures of reheat may vary, being lower for high-carbon steels and comparatively high for very soft steels and certain special alloy steels. The means of shaping the metal may likewise vary from the short, rapid, sudden blows of a high-speed hammer to the slow, powerful, kneading action of the hydraulic press. In all cases the aim is to subject the metal while at the proper temperature to such a mechanical action as will change its original "casting" structure and will give it a structure enabling it to withstand the kind of strains a casting cannot handle. Depending on the class of metal used and the service which the product is to render, the forging may be used directly as it comes from the hammer. It may also be simply normalized, which to all practical purposes means heat-treated in a manner to remove forging stresses, or finally it may be submitted to a regular heat treatment capable of still further changing the character of the grain and subatomic structure of the metal and thus imparting to it qualities which the forging operation alone cannot give. In all such cases products are obtained having qualities and characteristics of service that cannot be procured today by any other means.

The Vital Importance of Forgings to Certain Industries

If by some magic the art of forging were to disappear overnight, immense industries would be put to it to continue in existence. It is difficult to say how we could without forging produce, for example, locomotive and car axles, on which not only the efficiency but the safety of our entire transportation system depends. The automobile, which today is nearly as important a method of transportation for passengers and goods as the railroad, would likewise be scarcely possible without the forged axle, crankshaft, and connecting rods. Even if the forged axle could be replaced by some heavier shape, there is no question but that only a forging can withstand the stresses to which the crankshaft of the small, powerful, high-speed automobile engine is subjected. The absence of the same members, particularly the crankshaft and connecting rods, would make the airplane impossible also. The modern smokeless-powder rifle and machine gun would likewise have to go, because it was only the availability of a light, strong, and thoroughly reliable gun barrel that made the use of the high-pressure powders possible.

The foregoing are only a few of the huge industries whose very existence depends on their ability to secure good forgings, and if such products were not readily obtainable, numberless other lines of human activity would become disorganized.

Mechanical engineers have to use forgings in many ways. The forging industry in America is considerably in advance of what it is in the rest of the world in its ability to handle a large volume of production, this being due partly to American ingenuity and also to the immense domestic demand for forgings on the part of the railroads, the automobile industry, and the metal industries generally. With this in mind it is rather surprising that so little published information coming from domestic sources is available on the forging industry in this country. In England there are a number of excellent books varying in size from the little primer on Drop Forging and Drop Stamping, by Henry Hayes, to the large and informative treatises by Clifford O. Bower on Hydraulic Forging and on Practical Shell Forging. A number of excellent articles, chiefly for forge men, have been published in America, and whole periodicals are devoted to the art, such as *Forging and Heat Treating*, but all of these are for forge men—men who make the forgings. But when the man who is going to use forgings, the engineer who has to include forged parts in his design, etc., is taken into consideration, there appears to be a dearth of information, the only work available being apparently Drop Forging, Die Sinking and Machine Forming of Steel, by Jos. V. Woodworth, published in 1911, and therefore deficient in regard to the important developments brought about by the unprecedented demand for forgings during the World War.

The purpose of the present article is to give a brief survey of the status of the industry in America at the present time, and to collect within the limits of the space available such information on forgings as will be helpful not so much to the man who makes forgings as to the mechanical engineer who wants to know enough about the industry to be able to order forgings intelligently.

The heavy-forging business in the United States reached its peak while the World War was in progress and has noticeably receded since then. During that period the Crucible Steel Co. of America made heavy forgings at the Atha Works, Harrison, N. J., supplying material principally in connection with Government requirements. Because of the withdrawal of Government orders the operation of that department has been suspended. The experience of the American Bridge Co. was practically the same. They built a heavy forging plant at Gary, Ind., for the manufacture of heavy gun forgings, but after the war it was closed, and there are no immediate prospects of its resumption of operation. Moreover, the organization which operated this plant has been dissipated.

On the other hand, the production of medium-heavy forgings, especially for use by railroads and the automobile industry, has been very great and has reached a high stage of development not only as regards the volume of output but also in respect to the quality of material. And it is well to remember that the first drop forgings produced on a commercial scale were made in America by Colt in connection with the manufacture of his revolver.

Dies for Drop Forging

All forging work may be divided for the sake of convenience (this division is not claimed to be scientific) into drop forgings, medium-class forgings, such as railroad axles and shell forgings, and heavy forgings, to which belong such articles as big gun forgings, ship propeller shafts, etc.

Woodworth's work on drop forging describes a process of producing forged articles by the use of gang dies with edging, flatting, rough and finished stamping impressions. The practice is to forge the work in contour impressions on the edge of the die with a reasonable degree of accuracy before putting it in the finishing dies.

The first problem, which to a large extent determines the success or failure of production, is the preparation of the die. This requires very great skill and a thorough knowledge of the art of forging

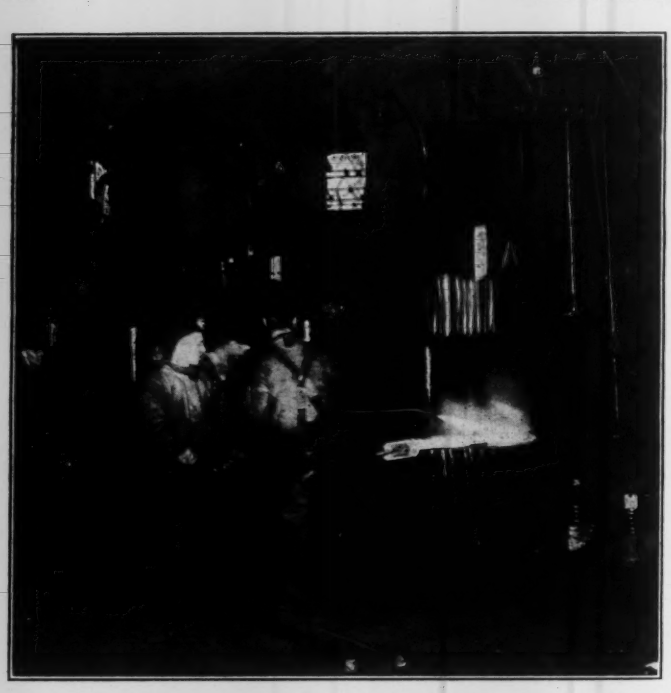


FIG. 1 STARTING THE FORGING OPERATION

There is a great difference between the forging operation and casting operation in that the metal under the forging hammer will not flow as easily and freely as the molten metal in casting. Therefore certain shapes which would be very easy to cast are impossible to produce by forging. Other shapes can be produced by forging but will be weak and unable to withstand stresses of a certain character and direction, and hence should not be used in members whose failure might prove disastrous.

The die maker, or rather the die designer, must be thoroughly familiar with all these facts and must also clearly understand the use to which the finished part will be put, as otherwise he will not be able to distribute the material in a proper manner. It is therefore very important that when an order is placed for drop-forged parts by an engineer who is not a specialist in forging himself, the final design shall not be given to the forging plant with general instructions to produce to blueprint, but that only a rough sketch showing the outline of the desired part be given and that this sketch shall be accompanied by the most complete information as to what service the part should be capable of performing. If the drop-forging plant knows what the part has to do, it will probably be far better able to realize this part in metal than would a man not familiar with the tricks of forging technique and the behavior of the metal under the hammer.

Once the design of the die has been determined—which really means the design of the part to be forged—the die itself has to be made. In the early days of the drop-forging industry when the number of parts to be forged was small and the hammers were comparatively weak, cast-iron dies were quite common. Today, with high labor charges prevailing in forging plants, it does not pay at all to forge a piece in a die unless a considerable number of pieces are involved, and under these conditions with the hammers at present used, the use of cast-iron dies has, as a general proposition, ceased to pay. Steel dies are used practically exclusively and the tendency is to employ such alloy steels as nickel, chrome-nickel, chrome-nickel vanadium, etc.

The die cutting as such does not differ materially from other similar operations where considerable precision in workmanship is required. After the die has been cut, a lead cast is made to show what the finished piece will look like. This cast goes to the chief engineer or superintendent of the plant for his approval. If the cast is approved the die is hardened, an operation which requires great skill in order not to produce distortion and possible cracking of the die block. In connection with the approval of the lead cast made from the unhardened die by the superintendent or chief engineer, it should be noted that the latter individual has as a rule come up from the ranks himself, and that in the past he has probably been a heater and hammer-gang boss and is therefore thoroughly familiar with the shop problems of those who will use the dies in actual production.

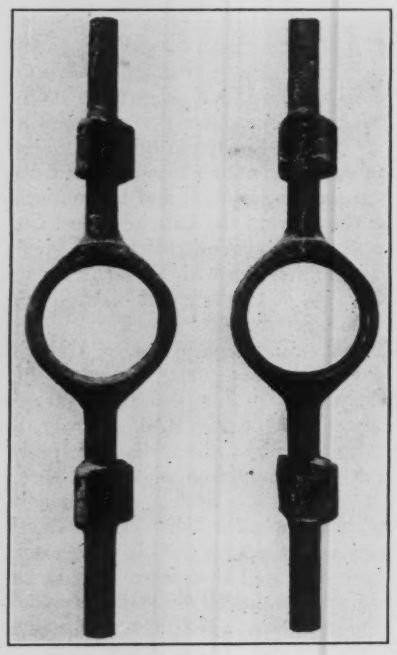


FIG. 2 BANJO AXLE PRODUCED IN THE DIES SHOWN IN FIG. 3

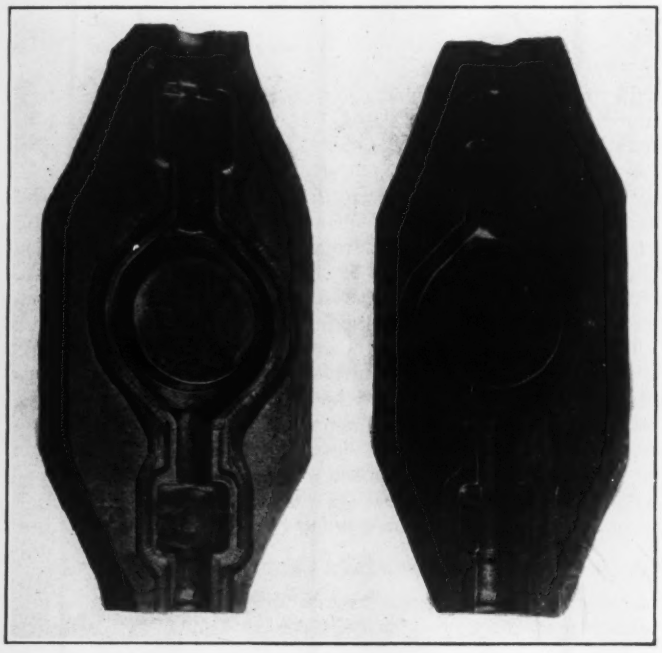


FIG. 3 BANJO AXLE DIES, CHAMPION MACHINE AND FORGING CO.

STEPS IN THE PRODUCTION OF HEAVY DROP FORGINGS

The first step in the production of the forged article is the selection of a proper material, which involves consideration not only of chemical specifications but also of shape and size. The billet, or "use" as it is called in England and in some plants in this country, has to be heated to a certain temperature. The temperature of the furnace in which this heating is carried on is usually considerably higher than the temperature to which the billet has to be heated,

and the conditions of operation in a modern drop-forging plant are not such as to permit the use of pyrometers or similar apparatus to measure the temperature of the billet, yet this latter has to be kept within a very close range. Not only this, but the temperature to which a billet is heated is materially affected by the character of the steel, and, for example, soft steel can be heated with impunity to a temperature which would be absolutely ruinous for high-carbon steel. The only way the proper temperature is judged today is by the color of the metal, and so great is the skill possessed by the heaters that the amount of waste due to overheated or underheated billets is surprisingly small.

The heated bar is next placed on the dies and the first blow delivered on it by the hammer. As the dies are covered with oil before the bar is placed on them, every one hurries away from the hammer before the first blow in order to avoid the shower of burning oil drops. The bar while being heated in the furnace becomes covered with a film of oxide, which is removed by a jet of steam. Fig. 1 shows these initial operations at the plant of the Champion Machine and Forge Co., Cleveland, Ohio. Good examples of modern drop forgings are the banjo axle and connecting rod manufactured at the above plant.

This axle, Fig. 2, is made from stock $4^3/_4$ in. square and requires five operations for its completion. The first operation takes place in a 2000-lb. steam hammer where the ends are reduced from $4^3/_4$ in. sq. to $3^3/_4$ in. sq., leaving sufficient stock in the center for the banjo and spring pads. To make the banjo the stock is forced into an oblong shape under a 10,000-lb. steam hammer and its center section punched out in a 1500-ton press. In the same press this oblong section is then spread apart until a circle about 13 in. in diameter is formed. The rough forging is then placed on the finishing die, Fig. 3, in a 12,000-lb. hammer and the forging operation completed, with the exception that the pads at each end are not at the proper angles. In the forging operation they are made straight across on a line with the banjo, but in the final operation, which takes place in a 1500-ton press, these pads are twisted to a 45-deg. angle. The forging weight of this piece is 375 lb.

FIG. 4 LARGE FORGED CONNECTING ROD FOR STATIONARY GAS ENGINE, CHAMPION MACHINE AND FORGING CO.
(Weight, 275 lb.; length, 63 1/2 in.; width, 4 1/2 in.; 10-in. opening at one end, 9-in. at other end.)

The connecting rod, Fig. 4, does not require as many operations to forge as the axle, and is not as heavy a forging. The first operation consists in reducing the center of the 4-in. by 9-in. stock to an approximate finished size in a 2000-lb. hammer, after which the ends are rough-forged in a 10,000-lb. steam hammer. The final forging operation is effected in a 12,000-lb. hammer when the full length of the rod is forged in one die, and in one stroke of the 1500-ton press the flash is removed and the center punched out of each end. There are 15 men used on this job. The forging weight of this piece is 365 lb.

DROP FORGING COSTS

The workmen in the drop-forging plants represent probably one of the highest types of skilled labor in the country. Conditions of work in front of the furnaces are rather trying on the human constitution, and moreover the men have to handle rapidly weighty masses of hot metal. This imposes a heavy physical strain, in addition to which the men have to be sure and quick of movement and possess a considerable amount of intelligence. This latter applies particularly to such men as the heater and the boss of the hammer gang. While accidents are not infrequent, the work generally does not belong to the dangerous forms of occupation.

It is only natural that men of such a grade should be highly paid. The usual system is to have a certain base figure per day but to pay the men really on a piece-rate basis, and it is not at all unusual for the final pay to be as high as twice the base daily rate, rising to $15 or more per day. The plant not only does not lose anything by this but is glad to have the men make the high rate, because this means a large production per tool, and the operation and maintenance of tools such as hydraulic hammers, billet-heating furnaces, etc., constitutes a very heavy charge on production.

Because of all this, under conditions of operation in a modern drop-forging plant it does not pay to produce articles required in very small quantities, and where such articles are produced their cost will naturally be very high. As a rough estimate it may be said that the production of fair-sized drop forgings costs at the rate of, say, $35 per hour. It should be understood, however, that this figure is merely a rough average estimate obtained from general

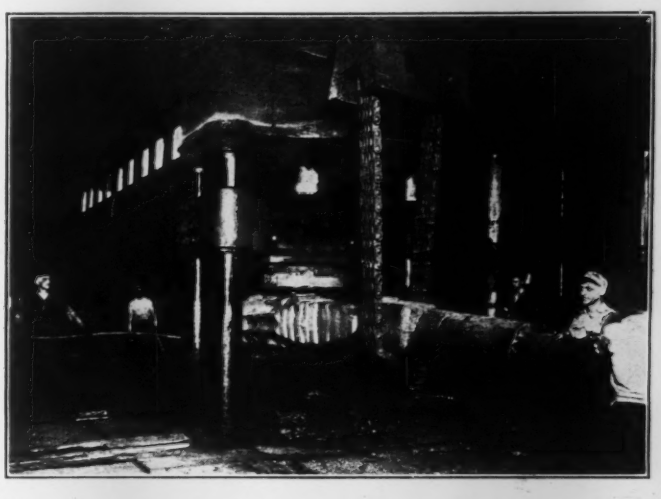


FIG. 5 FORGING A 32-IN. INGOT UNDER A 1500-TON STEAM HYDRAULIC PRESS (HEPPENSTALL FORGE AND KNIFE CO.)

FIG. 6 INGOT YARD AT THE HEPPENSTALL FORGE AND KNIFE CO.

statements made by several companies operating drop-forging plants and is intended merely to give a general idea of costs.

There is more to a drop-forging plant than just a furnace and a couple of hammers. A plant of that character to be capable of doing work of the high grade required, for example, by automobile companies, must have laboratory apparatus for investigating the grain structure of metal, etc., but above all, and this is what determines the success or failure of the plant, it must have as its head men who are not only thoroughly familiar with the forging operations as such but also with the character and properties of the metals and alloys handled and the behavior of the forged pieces under the conditions of service to which they are to be subjected.

FORGING HEAVY DIE BLOCKS

As an example of a plant specializing in the production of particular lines high-grade forgings may be mentioned the Heppenstall

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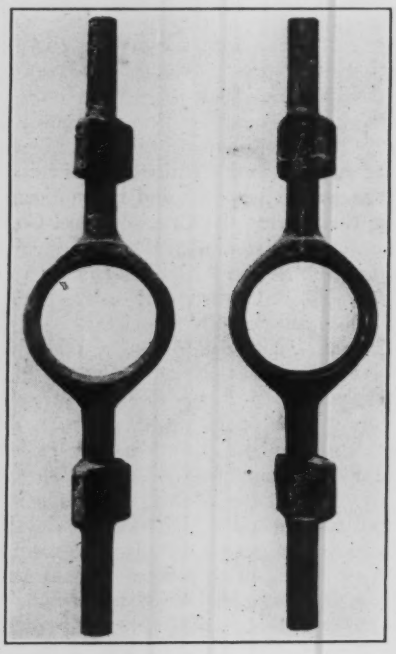

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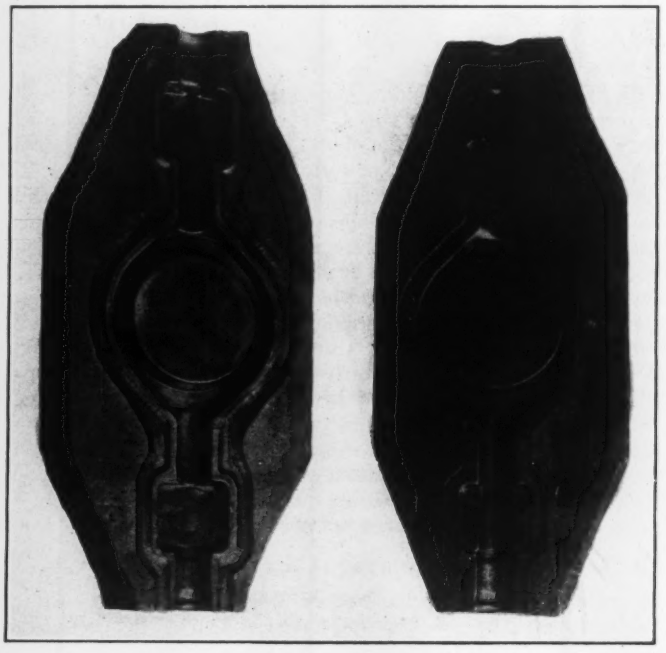

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It is only natural that men of such a grade should be highly paid. The usual system is to have a certain base figure per day but to pay the men really on a piece-rate basis, and it is not at all unusual for the final pay to be as high as twice the base daily rate, rising to $15 or more per day. The plant not only does not lose anything by this but is glad to have the men make the high rate, because this means a large production per tool, and the operation and maintenance of tools such as hydraulic hammers, billet-heating furnaces, etc., constitutes a very heavy charge on production.

Because of all this, under conditions of operation in a modern drop-forging plant it does not pay to produce articles required in very small quantities, and where such articles are produced their cost will naturally be very high. As a rough estimate it may be said that the production of fair-sized drop forgings costs at the rate of, say, $35 per hour. It should be understood, however, that this figure is merely a rough average estimate obtained from general statements made by several companies operating drop-forging plants and is intended merely to give a general idea of costs.

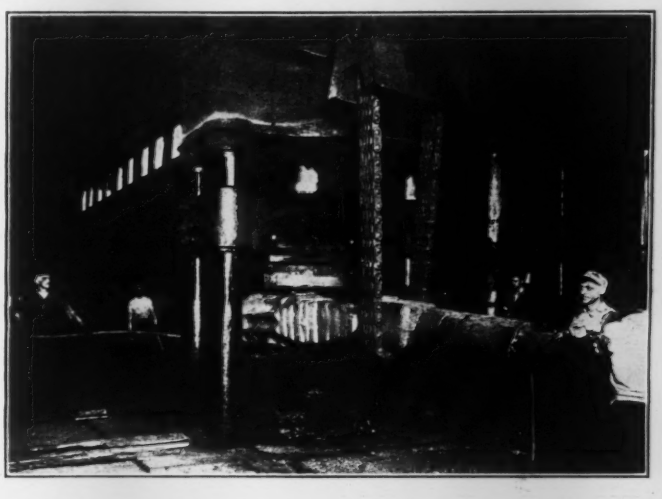


FIG. 5 FORGING A 32-IN. INGOT UNDER A 1500-TON STEAM HYDRAULIC PRESS (HEPPENSTALL FORGE AND KNIFE CO.)

FIG. 6 INGOT YARD AT THE HEPPENSTALL FORGE AND KNIFE CO.

There is more to a drop-forging plant than just a furnace and a couple of hammers. A plant of that character to be capable of doing work of the high grade required, for example, by automobile companies, must have laboratory apparatus for investigating the grain structure of metal, etc., but above all, and this is what determines the success or failure of the plant, it must have as its head men who are not only thoroughly familiar with the forging operations as such but also with the character and properties of the metals and alloys handled and the behavior of the forged pieces under the conditions of service to which they are to be subjected.

FORGING HEAVY DIE BLOCKS

As an example of a plant specializing in the production of particular lines high-grade forgings may be mentioned the Heppenstall

Forge and Knife Co.,[1] having its principal shops in Pittsburgh, Pa., and a subsidiary plant in Bridgeport, Conn. This company specializes in the production of die blocks and shear knives, in addition to which it also makes turbine bucket wheels and steel for oil drills.

In the matter of die blocks it was one of the earliest plants in the field. It is also claimed to be the first company in the United States to install a steam hydraulic press, which was used in the early part of the century to some extent in England.

Jewelers were among the first to use die blocks in this country, but those which they employed were very small. By the beginning

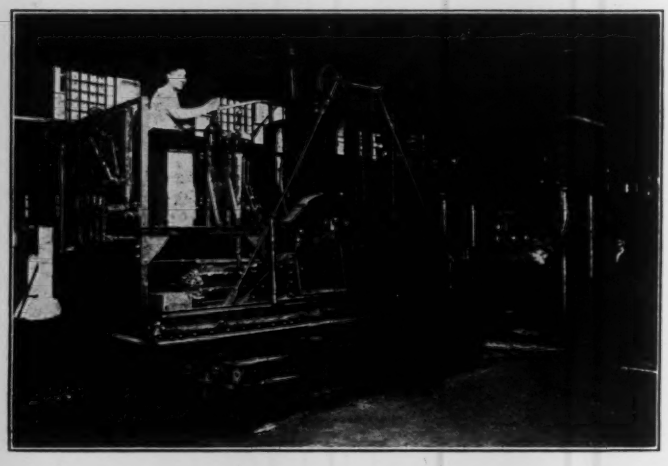


FIG. 7 FLOOR MANIPULATORS DEVISED FOR RAPID CHARGING AND DRAWING OF HEAVY BILLETS AT THE FURNACES

of the present century axe manufacturers had become the largest users of die blocks, requiring a size about $12 \times 10 \times 12$ in. With the further development of drop forging and the growth of the requirements of the automobile industry, the die block rapidly increased in size until it became too big to be handled by man power alone. Manipulators were then installed for use with the press or hammer, until now one man forges a 10,000-lb. die block and it has become possible to upset die blocks as long as 48 in. Fig. 5 shows a picture of a man forging a 32-in. ingot under a 1500-ton press, a thing that would not be possible except for the presence of facilities for manipulating the block.

The first die blocks were made from crucible tool steel, but as the size of the blocks increased, difficulties with such steel developed both in the way of methods of manufacture and costs. Attempts were made at first to lower the carbon content and increase the content of manganese. At a somewhat later date steels containing nickel, chromium, vanadium, molybdenum, tungsten, etc. were tried out. The most successful for die blocks proved to be a steel containing about $^3/_4$ per cent chromium and $1^1/_2$ per cent nickel.

While it was the early practice of all die-block manufacturers to send out their blocks as forged, leaving the question of heat treatment to the purchaser, the Heppenstall Company at least has abandoned that policy and now anneals all its die blocks, this insuring a uniformity of process and on the whole a far better product, because the company naturally has better facilities for annealing its own products and men more expert in handling their particular steels than would a buyer of die blocks not specially equipped to do the work.

The shear knives, another special line made by this company, also require forgings of a very high grade. The knives are hardened on four edges and are sometimes made in several large sizes, in fact, as long as 215 in. Some of these knives, for example, those made for the tin-plate industry, have to be very hard.

Many of the forge plants in this country buy their ingots. The Heppenstall Company has, however, a plant of its own, containing a 25-ton acid open-hearth furnace, and operates a 50-ton acid open-hearth furnace under a lease arrangement at another plant. In addition to this it has electric furnaces, but these have not been operated since the war. The ingots are cast in fluted ingot molds, top poured, although facilities are available for bottom pouring. Fig. 6 shows ingots which have been cold cropped and piled, with heat number and grade painted on each ingot. Special precautions are taken to prevent the removal of ingots on requisition from the forging department unless the requisition is approved by the metallurgical department. The purpose of this is to insure that ingots of the proper kind are used for each operation.

In the department devoted to die blocks the machinery is capable of handling ingots up to 32 in. in diameter, the principal unit being a 1000-ton steam hydraulic press. The pieces are handled by two floor-type electrically driven manipulators and two cranes, one 30-ton and the other 20-ton. One of the manipulators handles the forgings at the press and the other is used to facilitate the rapid charging and drawing of material at the furnaces. Fig. 7 shows one of these manipulators and gives an idea of its size, and incidentally of the cost of such a piece of apparatus.

In addition to this there are two other forge departments. One is capable of handling ingots up to 42 in. in diameter, and is equipped

FIG. 8 MACHINE SHOP FOR TURNING FORGINGS, HEPPENSTALL FORGE AND KNIFE CO.

with a 1500-ton steam hydraulic forging press which is served by six oil-fired heating surfaces. It has two 30-ton cranes and a 12-ton manipulator. Electrical rotating devices of an independent and removable type are provided for the cranes. These rotating devices were developed and built by the company for its own work.

The other forging department contains a 1000-ton steam hydraulic press with a manipulator, a 2000-lb. hammer, and a comparatively small (150-ton) steam hydraulic press.

There is finally what is known as a No. 1 forge department, designed to produce small forgings such as pinion blanks, small die blocks, etc. It contains a 2000-lb. and a 4000-lb. steam hammer and an 8-in. by 8-in. hot shear.

HEAT-TREATING DEPARTMENT OF A LARGE FORGE PLANT

The heat-treating department contains 11 furnaces of various sizes with equipment capable of heat treating forgings up to 40 ft.

[1] The information referring to the plant of the Heppenstall Forge and Knife Co. was chiefly obtained from the officers of the company during a visit of personal inspection by a member of the editorial staff of MECHANICAL ENGINEERING. In addition to this a few data were taken from a symposium describing that plant in *Forging and Heat Treating*, vol. 8, no. 9, Sept. 1922.

in length and 25 tons in weight. This heat-treating department is a very essential part of a plant of this character.

One of the interesting features of the Heppenstall plant is its oil-fired forge heating furnaces. Two designs of this furnace, differing only in detail, are in use—the end-fired four-door furnaces, used for heating the smaller sections of steel billets, and the side-fired single-door furnaces for heating ingots up to 42 in. in diameter and cogged billets from 8 in. by 8 in. to 25 in. by 25 in.

The end-fired four-door furnaces, of which three have been installed, are of the following general inside dimensions: 16 ft. 6 in. long, 6 ft. wide, and 2 ft. 4 in. high to spring of arch, with an air-preheating chamber at one end, partly closed off from the furnace by means of a perforated dividing wall.

The waste gas from these furnaces passes from the furnace proper through the perforated dividing wall into the air-preheating chamber, filling the same, and then escapes through two vents—one on each side—located at the top of this chamber.

U-shaped tubes of suitable size, made of extra heavy steel pipe which has been calorized to prolong its life, are submerged in the air-preheating chamber. The air for combustion passing through these tubes, at a velocity found by experiment to be suitable, absorbs sufficient heat to bring its temperature up to from 600 deg. fahr. to 800 deg. fahr. The temperature of the air-preheating chamber is from 1200 deg. fahr. to 1500 deg. fahr.

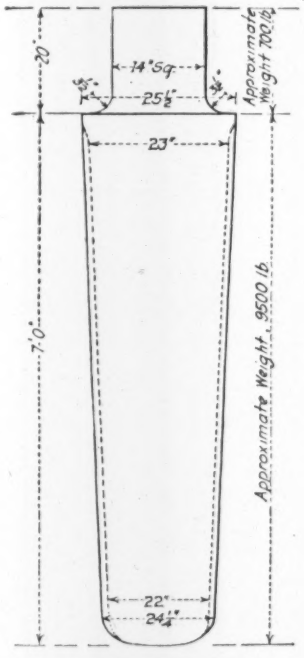


FIG. 9 INGOT WITH THE FLUTES MERGING AT THE TOP, PITTSBURGH FORGE AND IRON CO. (24-in. 12-flute bottom-poured hot-top ingot—acid open-hearth steel.)

The side-fired single-door furnaces are of several sizes but of the same general design, the larger being 16 ft. 6 in. long, 7 ft. 9 in. wide, and 5 ft. 3 in. high to spring line of arch, and some 14 ft. 6 in. long, 7 ft. 9 in wide, and 2 ft. 6 in. high to spring line of arch, all being inside dimensions. Naturally all furnaces are equipped with the same type of air preheater, which has proved satisfactory, and it should be noted that there are no stacks or chimneys provided for these furnaces, all waste gases escaping from the two vents located at the top of the air-preheating chamber and which were mentioned before, but the combustion is so complete that there are no smoke fumes or soot in the forge.

The Anthony Nebulyte oil burners are used and give very satisfactory results. Fuel oil is heated to within approximately 20 deg. of its flash point and delivered to the burner at about 75 lb. pressure. This burner breaks the oil into a very fine mist, and air at just sufficient pressure to break through this mist and intimately combine therewith is projected into it at a sharp angle, thus producing a gas before the mixture has traveled 4 in. beyond the burner nozzle. It should be understood that in this system air is not used to assist atomization, but to assure a rapid and controlled combustion. In this type of furnace, under average conditions, about 20 gal. of oil are consumed each hour of operation.

In viewing the Heppenstall plant as a representative of its type in the production of specialized forgings, it is seen to comprise a number of large and expensive tools such as big hammers, steam hydraulic forging presses, manipulators, furnaces, etc., together with a large machine shop, the size of which may be judged from Fig. 8. As the plant is producing only a comparatively small number of lines it has a good chance to train its personnel to a very high grade of efficiency and expert knowledge in those particular lines, and therefore attain a high quality of product.

In comparing machine shops with forge plants, it will be noticed at once that while the machine shop is a versatile establishment capable of readily changing from one line of production to another at practically a moment's notice, forge plants follow somewhat along the more specialized program of, say, modern hospitals, and just as an eye hospital would probably never think of undertaking a dental or abdominal operation, so the modern forging plant tends for the most part to keep within its own narrow groove. Such specialization, on the one hand, permits the use of specially adapted tools and specially trained personnel and thus makes it possible to attain a quality of product which would be difficult to secure in a shop of more varied and general productivity. On the other hand, such an arrangement presupposes a development of the industry great enough to keep a big plant busy on only a few lines. The amazing growth of the steel industry in this country—producing

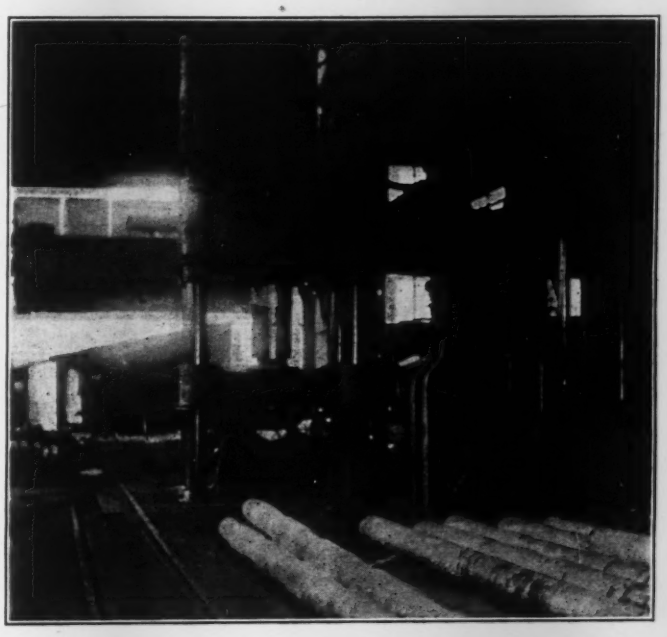


FIG. 10 HYDRAULIC PRESS WITH HYDRAULIC LIFT, PITTSBURGH FORGE AND IRON CO.

more than 50 per cent of the world's metal—and of the automobile industry, which stands without peer in the world, has made this possible, however, and all indications are that the tendency toward specialization will remain characteristic of the American medium- and heavy-forging industry.

A very important application of forging is in the manufacture of certain parts of railroad equipment which are subjected to such great and uncertain stresses that a material of the most reliable character is required. To this class belong locomotive driving axles, locomotive piston rods, crankpins, car axles, etc. There is still a good deal of disagreement as to what material should be used for these parts and how it should be treated. Some manufacturers advocate the use of heat-treated alloy steels, while others prefer such materials as normalized carbon-vanadium steel.

Because of their rigorous requirements railroads belong to the class of purchasers who are most difficult to suit, and they are growing more and more exacting every year. A lot of forgings which would have passed without question, say, about 10 years ago could not even be submitted today.

THE PRODUCTION OF VANADIUM-STEEL FORGINGS

It is proposed now to describe briefly the production of forgings in carbon-vanadium steel. Such steel is manufactured to the so-called specification 2-A of the Vanadium Corporation of America, and contains 0.45 to 0.55 per cent carbon, 0.70 to 0.95 manganese, and a minimum of 0.18 vanadium. Chromium as an impurity is permitted up to a maximum of 0.25 per cent.

The railroads in all cases of forgings of such character as axles require that a reduction of at least four to one be made from the ingot to the smooth-forged product. In connection with large masses such as locomotive axles, especially forgings 7 in. in diameter and over, it is the practice to recommend that they shall be hollow bored. According to a statement by the American Locomotive

Company, Schenectady, N. Y., this adds to the cost of the forging, but is money well spent, due to the fact that by boring it is possible to detect secondary pipes which might not otherwise be visible, and in addition it enables the manufacturer to produce a better grain refinement in the steel.

As an example of production of this class of forgings the methods used by the Pittsburgh Forge and Iron Co., Pittsburgh, Pa., one of the large producers of this class of product, will be described.

FIG. 11 CAR-AXLE FORGING HAMMER IN OPERATION, PITTSBURGH FORGE AND IRON CO.

The steel used for this class of forgings is of the acid open-hearth type with bottom-poured hot-top ingots. The ingots chiefly used are of the 24-in.-diameter type with 12 flutes. Contrary, however, to the usual practice of extending the flute uniformly to the top of the ingot, in this case, as shown in Fig. 9, the flutes merge at the top. One of these ingots is shown suspended in the air from the crane in Fig. 12 which is a view of the ingot yard of the Pittsburgh Forge and Iron Co. In the manufacture of the forgings a 1000-ton steam-hydraulic, high-speed forging press is used, but in this press both the upward and downward movements of the tup are hydraulically operated in contradistinction to the usual practice where the lift is operated directly by steam. This is, however, merely a detail of design and does not appear to affect the operation of the press. One such press is shown in Fig. 10. Fig. 11 shows a car-axle forging hammer in operation.

Another interesting feature of the methods used at the Pittsburgh Iron and Forge Co. is illustrated in Fig. 13, which shows the type of swage dies employed. Forge men differ considerably in reference to the character of the dies that should be used with hydraulic presses and their effect on the metal, some advocating flat dies or dies flat on top and rounded at the bottom, etc. It is claimed for the swage die shown in Fig. 13 that it produces a sort of kneading action which tends to displace the grain of the metal and thus improve its structure. From mere observation it would certainly appear as if the kneading action is secured with these dies. Microphotographs of the metal at different stages of forging might show whether and to what extent the difference in dies effects the character of the metal, but it happens that there are no such microphotographs.

As a rule, locomotive driving axles and crankpins are made under the steam hydraulic press shown in Fig. 10, the forging hammer of Fig. 11 being used for the production of M.C.B. or A.R.A. Standard car axles, locomotive engine-truck axles and locomotive piston rods.

The normalization process employed is essentially the one specified by the Vanadium Corporation of America as follows:

> The procedure to be followed in normalizing shall consist in allowing the objects, after forging, to cool until no color shows or to become cold. They shall then be uniformly reheated to the proper temperature to refine the grain, held at temperature at least one hour per inch of diameter, or thickness, and then removed from the furnace and allowed to cool in still air, protected from strong drafts, rain or snow. A group of forgings thus reheated is known as a "normalizing charge."
>
> Quenched and tempered forgings will not be accepted under this specification, and manufacturers furnishing forgings to these specifications, when required, shall certify to the purchaser or his representative that forgings furnished under this specification have not been subjected to quenching in any media other than contemplated in this specification.

THE PRODUCTION OF VERY HEAVY FORGINGS

The most spectacular branch of the forging industry is that producing the really heavy forgings—those weighing many thousands of pounds. This industry is of comparatively recent date, as it was only the large steam hammer—and especially the large hydraulic press—that made their production possible. Of recent years the development of alloy steels, in particular, chrome-nickel and chrome-vanadium steels, has opened up new fields for the application of forged pieces.

FIG. 12 INGOT YARD, PITTSBURGH FORGE AND IRON CO.

This end of the industry is a very specialized one, indeed All the equipment—heating furnaces, cranes, manipulators, forging presses, etc.—is of such huge size and such great cost that only few plants are capable of installing them, and it would take a large amount of business to keep such a plant going. As a matter of fact, there is not enough business available to keep many such plants in operation, which may be one of the reasons why plants established during the war for work on Government orders and which did not have back of them long-established selling connections that would supply them with orders in peace times, closed down after the armistice.

Another point which must be emphasized is that the manufacture of heavy steel forgings, whether of carbon or alloy steel, requires great skill, even greater than in the case of smaller forgings, both be-

cause of the greater size of the pieces and because on heavy forgings the amount of repetition work is comparatively small and each job represents a problem in itself. There are a good many pieces for which practically the only way of manufacture is that by forging; for example, heavy crankshafts. In this case no new principles are involved, but the size of the piece as illustrated in Fig. 14 as compared to the height of the man on the left is so great as to make the forging of the piece a real problem.

Fig. 15 represents one of the modern developments in the application of large hollow-drawn forgings, namely, a cylinder or reaction chamber used in connection with the manufacture of gasoline by the so-called cracking process. This cylinder is simultaneously subjected to heat, pressure and corrosion by sulphur in the oil, and in addition must be absolutely leakproof. Thus far forged-steel cylinders have been the only construction giving satisfaction. The ends are here shown open. As a matter of fact they may be either closed by heads of cast steel held by heat-treated nickel-steel bolts and nuts, or the heads may be made integral with the body. This latter can be done by forging the slope, neck, and flange at each end of the piece.

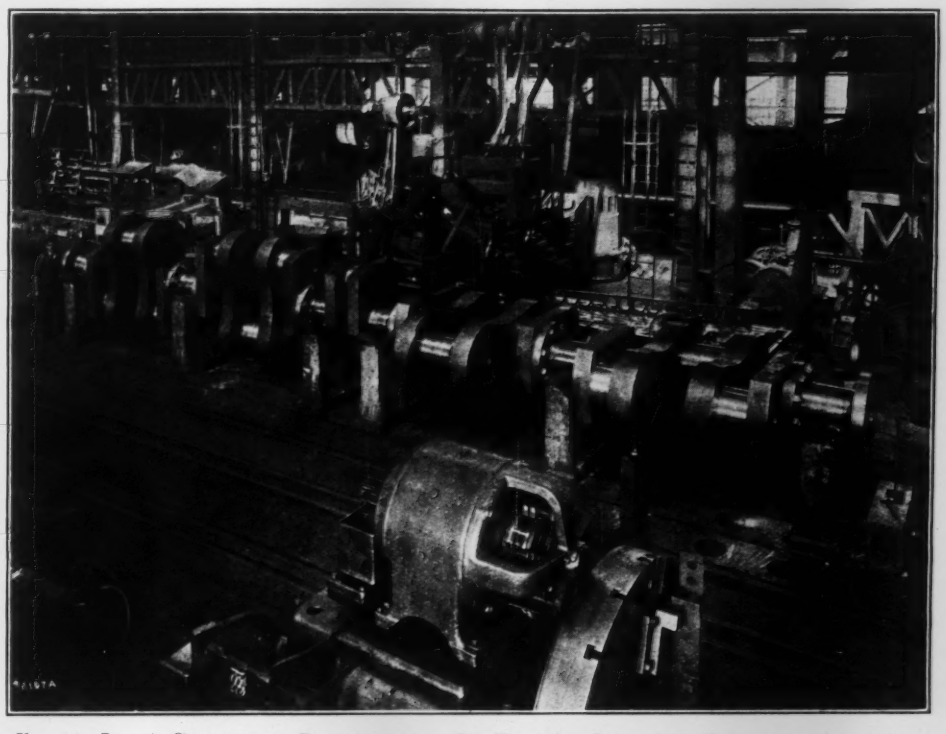


FIG. 14 LARGE CRANKSHAFT PRACTICALLY IN ITS FINISHED CONDITION, BETHLEHEM STEEL CO.

Another job of interest to mechanical engineers is the forging for the high-pressure boiler being built by the Babcock & Wilcox Co., at the Nicetown plant of the Midvale Steel Co., for the Weymouth Station of the Edison Illuminating Co. of Boston. It will furnish steam at a maximum pressure of 1200 lb. per sq. in. at a rate of about 110,000 lb. per hr. The cross-drum is a forged-steel cylinder 48 in. in inside diameter and 56 in. in outside diameter, with a total length of 34 ft. over the ends which are closed in to take a 12-in. by 16-in. manhole. The weight of this huge forging is 162,000 lb., requiring an ingot of 262,000 lb. to allow for scrap and losses. The billet was cut hot from a 78-in. octagon ingot, and then stood on end and upset to about 96 in. in diameter. Next a $23^1/_2$-in. core was removed with a hollow punch. The ingot then was expanded to about 50 in. inside diameter, sunk on a mandrel to 45 in. inside diameter and $58^1/_2$ in. outside diameter, and properly annealed and machined.

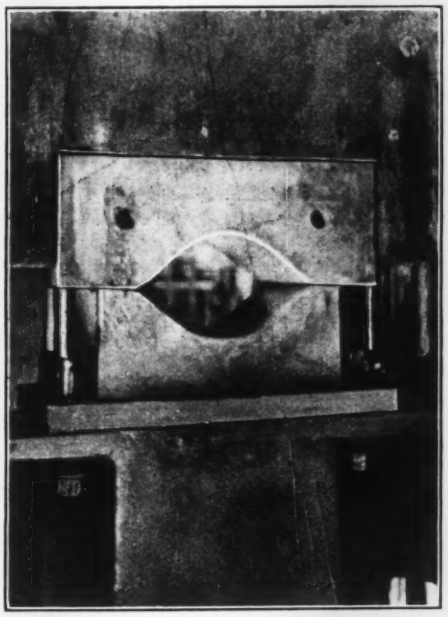


FIG. 13 SWAGE DIE, PITTSBURGH FORGE AND IRON CO.

FIG. 15 FORGING FOR REACTION CHAMBER OF OIL-CRACKING STILL, BETHLEHEM STEEL CO.

CRACKS IN FORGINGS

The following interesting discussion as to the occurrence of cracks in forgings is taken from a paper by John L. Cox on Producing Heavy Steel Forgings, read before the American Iron and Steel Institute, Oct. 25, 1923, and reprinted in *Iron Trade Review*, Nov. 1, 1923, pp. 1233–1236 and 1239.

Experience has shown, both in England and the United States, that solid forgings of large diameter, even of soft steel, may contain internal transverse cracks cutting across the axis, and sometimes running to within a few inches of the surface. Such forgings might drop in two in the lathe when deeply turned, although apparently perfectly sound had less metal been removed. If proper precautions be taken in casting, handling, forging, and treatment, such cracks are not produced, but as a check upon the makers the most enlightened buyers of such large forgings are today requiring the drilling of an axial hole in diameter sufficient to permit the introduction of a bore searcher (2 in. is about the minimum diameter) by which the interior surface of the mass can be easily viewed and its soundness verified. This should be made a regular requirement, both for the buyer's and the maker's protection. No reputable maker would wittingly send out such a defective forging, but if the buyer will not authorize boring the piece he has only the reputation of the maker as a guaranty of its soundness, unless magnetic or X-ray testing can be developed to include such sizes.

Many times the question has been raised to what extent the dendritic structure and other imperfections of the ingot persist

(*Continued on page 307*)

Power Organization in the Steel Industry

By BRYANT BANNISTER[1] and F. M. VAN DEVENTER,[2] PITTSBURGH, PA.

The authors show by comparison that the value of the fuels used and the complexity of problems incident to the operation of the power system of a representative steel works are of greater magnitude than for a representative central station. They contend that these facts warrant the existence of a highly qualified organization for a steel company in the nature of a power department. The paper describes such an organization and enumerates the benefits which should result.

ALL branches of the steel industry, from the mining of the ore to the fabrication of the finished product, require power in one or more of its various forms. Because of the diversity of operations characteristic of the steel industry, this power requirement is the only one common to all departments, with the exception of transportation which will be referred to again in this paper.

Power is produced and consumed certainly in greater quantities, and probably in more ways, by the steel industry than by any other industry in the world; and the consequent organization problems presented by the design and operation of the many elements of the power system require a thorough analysis for their proper solution. The fundamental problem is not one of technical engineering alone, but of organization to properly direct the activities of the talent already available.

The magnitude of the power requirements of this industry can best be illustrated by reference to the fact that the amount of fuel used in producing this power is two-thirds of the amount used by all the coal-burning central electric-power stations in the United States.

Steel Works vs. Central-Station Power Requirements

A five-blast-furnace steel works with a full complement of rolling mills and finishing equipment is representative of a moderate-sized plant. Such a plant requires about $2,000,000 worth of fuel annually to generate the power and producer gas required for its operation. A public-service central station with an annual peak load of 100,000 kw. and a 60 per cent annual load factor is representative of a moderate-sized central station. Such a station would require about $1,500,000 worth of fuel annually for its operation. These figures indicate that the value of the fuel used by the steel works is considerably greater than the value of that used by the central station, and this example is believed to be representative since, although there are many central stations larger than the one cited, there are also a number of steel works of more than double the number of furnaces mentioned.

The operation of a cental station involves the use of only one fuel—usually coal; whereas the operation of a steel works involves the use of many fuels—coal, blast-furnace gas, coke-oven gas, tar, oil, coke breeze, natural gas—and waste heat. When the diversity of the power requirements and the variety of fuels used in the steel works are considered in conjunction with the value of fuel consumed, it is apparent that the need of an adequate organization to direct the production, distribution, and use of power is even greater in the case of a steel works than in that of a central station.

The load factor at which power equipment is to operate is recognized as one of the most important factors in the selection of the type of equipment to be used. For example, a power station operating on a base load can usually justify the installation of many appurtenances such as economizers, stage heaters, air preheaters, etc., because the value of the increased fuel economy obtained will pay a net return in addition to the fixed and operating costs involved by the use of such supplementary equipment. On the other hand, a steam stand-by plant built to supplement a hydro-electric development cannot justify expenditures for much more than the essential elements of a plant, since the fixed charges on supplementary non-essentials, which charges continue during non-operation, would exceed the value of the fuel saved during the few hours the plant would operate during the year.

Steel-works power units generally operate on a high load factor, since most departments continue throughout the 24-hour period and the diversity of load is such as to yield a comparatively uniform demand on the power system. Most modern central stations are designed for high-load-factor operation under base-load conditions; but when extensions are made to the plant better economy may be had from the new units because of improvements in design, and as a result they are given preference and the older units are operated at a load factor much lower than that for which they were designed. Under this influence many central stations or component units within a station designed five to ten years ago for 70 per cent load factor are now operating at less than 20 per cent load factor, the average load factor for their useful life being below 40 per cent.

The high load factor which obtains at steel-works power plants warrants the consideration of all types of supplementary equipment, and a thorough analysis of the conditions so as to incorporate in the system the type and size of equipment which will yield maximum service for minimum capital outlay.

Occasional fuel shortages and present high fuel and labor costs make it advisable for the steel industry to encourage economy in the production and consumption of power. The greatest opportunity for improvement in this phase of the steel industry's activity has not been apparent because of the practical absence of any distinctive organization controlling these activities, and it is the purpose of this paper to analyze the advantages of such organization and outline its practical construction and application.

Elements and Problems of The Steel-Works Power System

In any steel company the producing departments are served by certain elements which, because of their character, naturally lend themselves to consolidation into a "power system." These elements are as follows:

1 Power station including boilers, turbo-generators, pumps, switchboard equipment, feedwater purifying plant, etc.
2 Mill service-water pumps and distributing system
3 Central coal-handling plant and distributing system
4 Waste-heat boilers and steam-distributing system
5 Air compressors and compressed-air distributing system
6 Hydraulic power pumps, pipe lines, accumulators and control equipment
7 Blast-furnace blowing equipment
8 Heating and ventilating equipment
9 Substations, mill motors, lighting and electric transmission system.

These items are closely related, and the necessary engineering and operating supervision is of a character quite different from that required by other departments of the works. The fact that these items are common to more than one producing department, with few exceptions, is an added reason for their consolidation. The transportation equipment, which also serves *all* the departments of a steel works, is now usually consolidated into a railroad system, under the supervision of a separate organization which is highly specialized in that particular kind of service.

The problems presented by the power system, in addition to those imposed by the works at large, cover a field of engineering too broad for a single specialist. The full significance of this can best be appreciated by considering those activities within the scope of the power system alone, which should be promoted if best results are to be obtained: namely,

1 Power engineering in connection with plant extensions and modifications
2 The study of existing works conditions for the purpose of determining what improvements should be made
3 The study of the power system as affected by changes in manufacturing methods; e.g., the installation of by-product coke ovens for metallurgical purposes will materially change the whole scheme of power production
4 The investigation of new developments in power equipment
5 The development of power equipment in coöperation with the manufacturer.

[1] Power Engineer, National Tube Co. Mem. A.S.M.E.
[2] Mech. Engr., Power Dept., National Tube Co. Jun. A.S.M.E.

Contributed by the Power Division for presentation at the Spring Meeting, Cleveland, Ohio, May 26 to 29, 1924, of The American Society of Mechanical Engineers. All papers are subject to revision.

THE ENGINEERING ORGANIZATION

The engineering organization which would be required to do full justice to the five lines of activity just enumerated, would be directed by a company power engineer, whose office would be in the nature of a clearing house for data and suggestions, which would be applied to power-system requirements by more specialized engineers in the realms of electrical and mechanical engineering. The full time of the electrical engineer would be required in the investigation of improvements in his art, the application of which, to the steel industry, is still in its infancy and offers a tremendous opportunity for further development. The mechanical engineer would be confronted by still more diversified problems since mechanical engineering has undergone such rapid and extreme changes that equipment and processes which were considered standard a few years ago are now obsolete. Further subdivision of these main departments is desirable because of the great diversity of requirements within each, and such subdivision would be possible where the volume of work would require suitable talent in each section. Both the diversity of problems and volume of work, obviously, would be greater for a central department than for any one of several works organizations.

The outstanding advantages accruing from a central engineering department, adequately organized to cover the multiplicity of power problems, are—

1 Most intelligent investigation of works conditions, giving proper recognition to such improvements as may be either necessary or justified by the return on the cost involved. This would work toward a lessening of casualties and lost time due to breakdowns and power shortages

2 Uniformity of design and type of equipment, making possible a comparison of operating results, thereby promoting friendly rivalry between works for supremacy in operation

3 Mistakes in judgment in the design or selection of equipment would not be repeated. There are instances where one company has removed equipment because it was considered obsolete and another company later installed the same class of apparatus; in fact, one works of a company has installed a certain type of equipment which another works of the same company has discarded

4 The psychological effect of having a responsible organization dependent upon results for its permanence. Thus the power department would strive each month and year to show that it had maintained a better record of continuity of service and operating economy than in preceding periods, just as departmental superintendents strive to improve their production records.

It should be borne in mind that the many component parts of the power system are like the links of a chain, rendering the old adage that "a chain is no stronger than its weakest link" entirely applicable. Since the whole system is limited by the weakest element, the unit cost must be based upon the capacity of this element, which tends to inflate installation costs unless the system is well balanced throughout. For example, there are boiler installations where, originally, insufficient draft was provided through failure to analyze correctly the gas conditions, requiring the installation of additional draft equipment before the expected capacity could be obtained. Improper treatment of boiler feedwater sometimes causes foaming and priming, thus limiting the rate of steam production, where the equipment would otherwise have greater capacity. With the organization proposed, comprising proper talent, it is to be expected that the expenditure of funds for extension and improvements would be most judicious, and the installations so provided would be superior, at a lower cost, to those usually engineered and installed under the present system.

Generating stations built by public-service corporations will be found to comprise the latest and best equipment, to be provided with instruments for determining and recording the performance, and surrounded by a building of architectural beauty at less cost, and at the same time more economical, than a station of equal capacity built along the lines usually followed by industrial concerns.

The superiority of a central organization over separate power-engineering departments at each works has been shown by a consideration of the results obtainable. In addition to this, the cost of such departments at each works would be prohibitive in comparison with that of a central department highly qualified for the work involved.

THE OPERATING ORGANIZATION

It has been pointed out that a central engineering organization is essential, but the very nature of operation requires an operating organization at each works, of sufficient size to handle the daily volume of work and meet any operating emergency. Because of the intimate relationship between the power-system and the producing departments, the failure of any power-system element is likely to be felt throughout the works. Most producing departments, if properly managed, are able to maintain a stock which in case of emergency is available for the succeeding operations, and interruption in one department does not necessarily affect the remainder of the plant. Since the power system cannot accumulate a stock of its product, any interruption in service immediately interferes with the operation of dependent departments, rendering continuous power service of such importance that every reasonable precaution should be taken against methods of operation which are not consistent with maximum reliability. This can best be accomplished by placing the responsibility for the operation of the entire system upon a power superintendent, thereby relieving the producing department heads of responsibility for such power-system elements as may now be included in their departments. Any department superintendent, to be proficient, must be familiar with the equipment of his department and skilled in its operation. In addition to the daily management of the department, it is his fundamental duty to study operation for the purpose of furthering development. It is therefore important that the scope of work under the direction of one superintendent be confined to those activities which require supervision of a similar but distinctive character, and which, if properly executed, would claim his full time and study. One in such a position of responsibility would hardly be qualified by capacity, experience, or inclination to carry further responsibilities which reach beyond the natural limits of his department.

The power superintendent should have the same standing relative to the works manager as other department heads. This would insure for the power system the same consideration as given other departments, and would provide suitable representation at meetings for the discussion of general works problems. The fact that the nine elements of the power system serve *all* departments of the works is a further reason that it should be given its proper place in the industrial organization as a whole.

The application of modern power equipment employing high pressures, temperatures, voltages, combustion rates, and rotative speeds, and the increased size of units combine to present an operating problem requiring skill and judgment of a character entirely different from that required a few years ago, and quite foreign to the problems of any producing department. The full possibilities of modern apparatus can only be realized by most skillful operation, requiring the direction of a superintendent who understands the theory of design and construction of equipment under his supervision, and who has previously received both technical and practical training. The sub-heads in charge of the various divisions should have a practical knowledge of operation and be able to interpret and carry out instructions and to act properly in emergencies; the remainder of the force should be faithful to duty and need have only sufficient ability to follow instructions.

The scale of wages in the power department should be consistent with those paid in other departments for an equal degree of skill, intelligence, and physical exertion. There should be a general scheme of promotions to encourage capable and ambitious workmen, and to insure advancement in the order of skill and experience.

Centralized responsibility for the operation of the power system would make possible a marked saving of both fuel and labor, and at the same time increase the reliability of equipment. Since the chief function of the department is to maintain service at as low a cost as possible consistent with safe operation, reliability and economy would be paramount issues.

APPLICATION OF THE PROPOSED SCHEME OF ORGANIZATION

The coördination of the power-engineering and operating departments would insure the combination of equipment best suited to the

needs of the works at large, and at the same time render available the latest and best ideas and developments in equipment.

In many instances within the last ten years the steam engine has given way to the steam turbine, the reciprocating pump to the centrifugal, the engine mill drive to the motor drive, and the blowing tub to the turbo-blower. The vast improvement wrought by these substitutions is recognized, but the users can claim little credit for their inauguration, since the development has been initiated and promoted largely by the manufacturers. The financial return realized by the user of any improved apparatus is many times greater than the profit to the builder. A rolling mill creates a value in the material passing through it which in a short time exceeds the original cost of the mill; likewise a turbo-generator consumes steam at a rate which soon amounts to more than the original cost of the installation; hence any slight increase in production, betterment of product, or improvement in economy will result in a much greater profit to the user than to the manufacturer of the equipment. The user, therefore, should have greater incentive to develop equipment incident to this industry than the manufacturer, and the user's organization should not only be capable of determining what improvement and developments would be advantageous, but should coöperate with the manufacturer in their development. The power organizations as outlined, if given the proper rank, would not only perform their daily duties, but in addition would render valuable service in the development of improved equipment.

It is realized that, for the average industrial concern to initiate the schemes proposed, many changes would be required, some affecting organization, and others, general policy. The accruing advantages, however, justify these changes. The first steps in the development would be appointment of a power engineer, who because of the other divisions of engineering comprising a company's requirements, would report to the company's engineering head, and the appointment of a power superintendent at each works, reporting to the works manager. Further development of these departments would depend upon the character and extent of works activities. In order to insure proper coöperation between the engineering and operating departments, all recommendations and instructions emanating from the engineering department should be discussed and an agreement reached with the power superintendent at the works before a report is made. This report, bearing the approval of the power engineer and the power superintendent, would then be submitted to the works manager for final approval. In this way an agreement between the engineering and operating departments would be reached before changes were made; and at the same time matters that the engineering department considered worthy of treatment would, of necessity, receive the attention of the works. When the purchase of equipment was involved, the engineering department would issue a purchase recommendation, tabulating the various bids and giving comprehensive reasons for the selection made. This would have the combined advantage of keeping all the transactions on record and of placing the operating department in a position to approve, or show in writing substantial reasons for not so doing. It is believed that few mistakes would result from such a procedure. The works, of course, would issue the necessary requisitions covering the equipment to be purchased.

The foregoing presents briefly the reasons for centralizing responsibility to direct the engineering and operation of power systems, and outlines the method for accomplishing this without radical changes in existing organizations, showing that the results obtainable amply justify any changes that may be involved.

CONSOLIDATING THE POWER INTERESTS OF A CORPORATION COMPRISING SEVERAL COMPANIES

This treatment of economical power development so far has dealt with a single works, or a company comprising several works, but to make the study comprehensive of the largest elements of the steel industry, the case of corporations comprising more than one company will be considered. Such corporations were formed to pool the resources of the constituent companies to bring about maximum economies of operation at minimum cost. The power systems of the constituent companies have so much in common that it is not only feasible but economical to consolidate them as far as possible.

Logically, the simplest organization scheme to bring about a consolidation of the power interests would be through a corporation power engineer, who would serve in the capacity of chairman of a power-engineer's committee, comprising the various companies' engineers. This committee would meet at regular intervals to discuss their various problems, and serve as a clearing house.

A corporation power committee would function to standardize the development of power, resulting in uniformity of equipment and making possible consideration of problems entirely beyond the scope of even the most fully developed company organization, in fact, considerations which are inherently dependent upon centralized control. In general, the advantages accruing from such centralized control would come from the consideration of all works as a single property; and where several works are located in one district, a pooling of their power equipment and resources, which would result in the maximum utilization of all available by-product power for distribution to the best interests of the corporation. In this way surplus power from any works would be made available for other works within reach, where solid fuel would otherwise be required. This consolidation of interests would eventually result in much greater economy than would be possible if each work's or company's problems were considered separately.

Certain members of the corporation committee could be detailed to investigate new developments brought to the attention of the committee, and a report formulated for presentation at a future committee meeting, thereby keeping the entire committee fully acquainted with most recent developments in the power-engineering art. Other subdivisions of the main committee could be detailed to make tests of new equipment installed within the corporation, or perhaps elsewhere, from which pertinent data would be derived, to determine the best operating conditions and to aid in the selection of future equipment required at any one of the corporation's works. It is believed that such a procedure would place the corporation in a position to take advantage of the most valuable developments applicable to the steel industry, and would provide a means for utilizing the best talent within the corporation for making any specific investigation.

Broadly speaking, this form of organization is based upon the same considerations which bring about the consolidation of separate companies into a corporation.

FOR steam pressures above 400 lb. the use of the single-cylinder turbine in capacities above 35,000 kw. entails a serious sacrifice of efficiency, and compound units should be used.

For given steam conditions and a given cycle of expansion, the limitation of the capacity of the turbine is the area of the last row of blades through which the steam is discharged. If the capacity is increased without enlarging the area of the last row of blades, steam must escape through this area with added speed or velocity. This means that there will be greater losses, due to the velocity of the leaving steam which should have been turned into work.

A 50,000 kw. cross-compound unit for 600 lb. steam would ordinarily be designed with the high-pressure element to carry 10,000 kw. at 1800 r.p.m. The low-pressure element would operate at the same speed.

A 40,000-kw. cross-compound unit designed to operate at a steam pressure of 1200 lb. would probably have a high-pressure element at much higher speed, in order to maintain physical dimensions that are reasonable, and to insure high efficiency. In case of higher pressures, such as 1200 or 1500 lb., there would be an additional high-pressure unit, making three units in all of the complete cross-compound machine. With steam entering the intermediate element at 300 lb. an impulse wheel would be used. For entering steam of 130 lb., however, the impulse blades would be removed, while for 180 lb. of entering steam a single-row impulse wheel would be present, in addition to reaction vanes.

On the reheating cycle, a large volume of steam is stored in the reheating system. Provision must therefore be made to prevent excessive overspeeding in case the load were taken off and the main valve to the high-pressure unit closed. The emergency governor should operate a butterfly valve in the heating system, and also a relief valve, so that the steam could be cut off from the lower pressure unit and exhausted directly into the condenser.—Linn Helander, Mem. A.S.M.E., before the Providence Engineering Society, Jan. 4, 1924, as reported in *Power*, April 1, 1924, p. 543.

The Solid-Injection Oil Engine

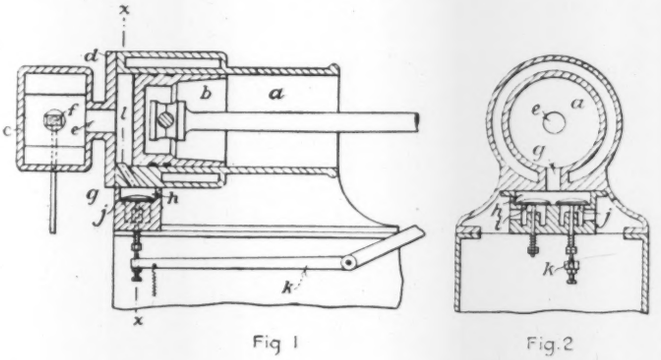
By H. F. SHEPHERD,[1] SPRINGFIELD, OHIO

The development of the solid-injection oil engine during the past three years has engaged the attention of many designers. Unfortunately, most of the information gained by experiments has been withheld from publication and the net result has been a duplication of laboratory and test-floor effort. The author has undertaken to present the most pertinent facts on the development of the engine from the former hot-surface unit and points out the influence of combustion-chamber design, spray angle and velocity, atomization, detonation, and other problems confronting the oil-engine designer.

THE development of the principles of solid injection has required a far longer period of time than did the development of the full-Diesel engine with air injection. It is safe to assume, however, that equal technical ability was brought to bear on both types, for Dr. Diesel first concerned himself with solid injection and abandoned it for what he considered good reasons. Rundlof first employed solid injection, then a compromise system using moderate air pressure, and later returned to solid injection. Jacob Gunther used air injection and finally developed a notably successful system of solid injection, while Hesselman, an international figure in Diesel-engine design, has lately produced an outstanding solid-injection model.

From these events it may be inferred that the design of the solid-injection engine has presented some difficult problems. Undeniably it has, but it is most pleasant to testify that progress has resulted in simplification of theories and practice. The modern solid-injection engine is as much a "rational heat motor" as the modern Diesel engine.

Rationalization of solid-injection-engine design has had to await



FIGS. 1 AND 2 PATENT DRAWINGS OF HORNSBY-AKROYD ENGINE

the oil-engine man's education concerning the properties of petroleum, especially its behavior when subjected to heat, an influence less prominent when air injection is used. The experimenter had still further to extend his investigations into the hydraulic problems introduced by the injection system itself, and to extend his tests and observations in thermodynamics beyond that more familiar section dealing only with heat and work into a thorough study of conductivities, as will appear. With a brief historical sketch as foundation and evidence, the author proposes to discuss his present views regarding the true actions within the solid-injection engine.

HISTORICAL

It is well known that Herbert Akroyd Stuart proposed a solid-injection engine prior to Dr. Diesel's first experiments. He covered this idea in British patent No. 7146, dated May 8, 1890, describing

> ....means for preventing the premature or pre-ignition of an explosive charge of combustible vapor of gas and air when a permanent igniter (such as a continuous spark or a highly heated igniting chamber) is in communication with the interior of the cylinder, by first of all compressing the necessary quantity of air for the charge and then introducing into this quantity of compressed air the necessary supply of combustible liquid, vapor or gas to produce the explosive mixture.

Unfortunately this engine was never known to commerce and Akroyd Stuart turned to a principle more in keeping with the low-pressure practice of that day. In British patent No. 15,994 A. D. 1890, he describes what we know as the Hornsby-Akroyd engine, which for some years, despite all its faults, was the best hot-surface engine available. In this latter patent specification he states:

> When liquid hydrocarbon is employed the injections may be so timed as to occur at the beginning or at any portion of the suction stroke or during the compression stroke. We prefer, however, to give sufficient time for complete vaporization in order to obtain the maximum economy of combustible liquid and this can be accomplished by injecting the hydrocarbon during the suction stroke when the combustible liquid after coming into contact with the hot walls of the explosion chamber vaporizes very completely and occupies the combustion space.

The scheme of this engine is presented in Figs. 1 and 2 by means of the original patent drawings. Oil entered the hot chamber *c* through the spray *f*. The injection pump was driven by the down-

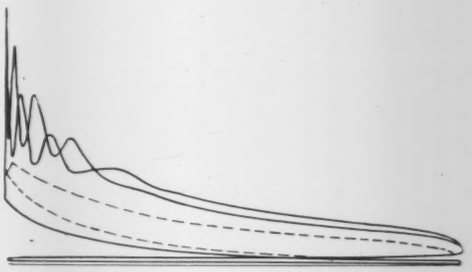


FIG. 3 INDICATOR DIAGRAM OF HORNSBY-AKROYD ENGINE

ward stroke of the inlet-valve lever so that injection occurred during the first half of the admission stroke.

Akroyd Stuart proceeds with his description:

> No mixing sufficient to cause an explosion will take place owing to the contracted area of the communicating passage until, on the return or compression stroke...sufficient air is forced...into the explosion chamber to produce a mixture capable of explosion. The cubical contents of the engine cylinder and the explosion chamber are so proportioned that the mixture in the explosion chamber during compression is rendered explosive in time to secure the ignition at or near the end of the compression stroke.

In a measure the engine accomplished its object. It was a vast improvement over the external-vaporizer models of the day. At full load it gave a very creditable Otto-cycle card as shown in Fig. 3, but at lighter loads with smaller charges the relations were destroyed; the explosive mixture was produced earlier and cards such as shown by the broken lines resulted. The isolation of the combustion chamber, serving to localize the carbon produced by excessive heat and prolonged "cooking" of the oil, was, in that day, a real virtue. Several attempts were made to rationalize the dimensions and proportions of this engine, but, as far as the author's information goes, they all came to naught.

About the year 1913 Louis Doelling undertook experiments along this line. He brought to the work an advanced knowledge of sprays and a better understanding of the requirements of the fuel pump and possibly a full faith in the possibilities of the original Akroyd Stuart idea of injection at firing time. He reduced the clearance *l*, Fig. 1, by successive stages. Improvement resulted with each reduction. Desiring then to eliminate the valve-pocket clearance *h*, he resorted to the design shown in Fig. 4 with injection timed to the moment of firing and a new and greatly improved commercial engine resulted, the De La Vergne D. H. A full-load diagram is shown in Fig. 5 and a quarter-load diagram in Fig. 6. In the course of further development the spray angle was gradually elevated with notable improvement, greatest economy resulting when the spray was directed to meet the air entering the neck rather than when striking the hot surface directly in the old mode. The form of the hot surface was then altered to that shown in Fig. 7.

[1] Consulting Engineer, Foos Gas Engine Co.

Contributed by Gas-Power Division and presented at the Annual Meeting, New York, December 3 to 6, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

Out of this, by the happy combination of two such slopes as shown in Fig. 4 and two such sprays, came the Price engine, Fig. 8. The convention date on the patent issued to the late Wm. Tudor Price is Dec. 10, 1917.

The dates succeeding the original Akroyd Stuart patents are not cited to show priority. Rundlof obtained rational working in the Bollinder engine before the appearance of the D. H. engine. The author had accomplished like results in the Bessemer engine in 1913, but this particular succession reveals progressive development from the primitive to what may be a final development.

Our knowledge of oil-engine working was probably delayed by the contemporary theories of the actions within the Hornsby-Akroyd engine. Most of us came to the craft with firm impressions of the necessity of an unscavenged vaporizing chamber, of the significance of the relative clearance inside and outside of the chamber, and of

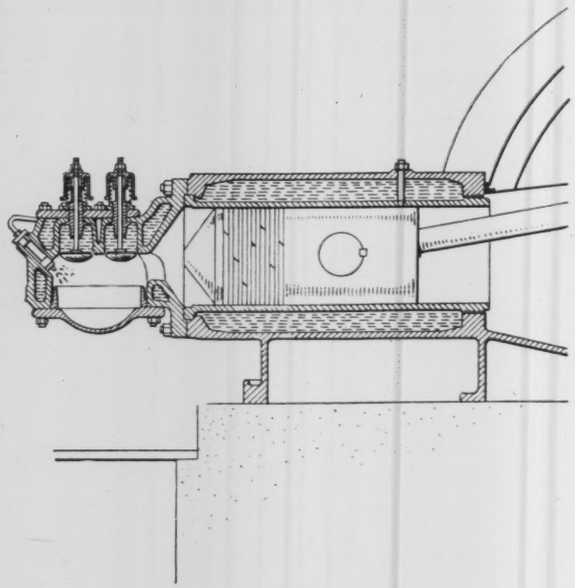


FIG. 4 THE DOELLING ENGINE

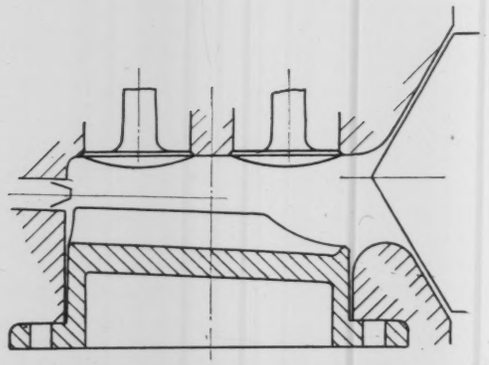


FIG. 7 DOELLING ENGINE WITH FORM OF HOT SURFACE ALTERED

the mystic and undetermined action of the neck or contracted passage dividing the combustion chamber into two parts.

The Doelling-Hornsby engine as the next descendent clearly showed improvement with its single-scavenged combustion cavity. The improved Doelling-Hornsby engine demonstrated the secondary importance of the hot surface, and the Price engine, obviating the hot surface entirely, demonstrated that the air charge itself when compressed to the proper degree may perform the vaporizing function.

In January of 1894 Dr. Diesel, having already established the possibility of securing spontaneous ignition by the injection of fuel into an atmosphere heated by compression, undertook a series of experiments on the method of introducing fuel. Quoting by free translation from his book, Die Entstehung des Diesel-motors, his impressions seemed to be as follows:

Next, injection by means of the fuel pump direct, only an automatic valve in the nozzle, over the seat surface of which a conical distribution and atomization of the fuel shall take place. The operation is entirely unreliable. The degree of atomization observed under various pressures: at high pressure good; at low pressure uninterrupted jets without the least atomization.

Further experiments, injecting direct with the pump and simultaneous opening of the mechanically operated spray-valve needle. The pump plunger and spray-valve needle are linked together and operated by the same cam. Injection very precise.

Next the pump was set aside and it was sought to accomplish injection by mechanical operation of the needle, the fuel pipe being kept under constant pressure. After these trials in the open air followed tests in operation with direct injection out of the fuel pressure pipe; ignition excellent. Exhaust gases burning still as they leave the cylinder, the spray valve is most unreliable, injection uncontrollable, the system must be abandoned.

Dr. Diesel's next step was to apply air injection with astounding and lasting success. Figs. 9 and 10 show the fuel pump, the various

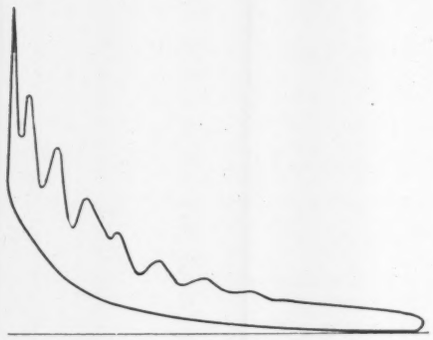


FIG. 5 FULL-LOAD DIAGRAM OF DOELLING ENGINE

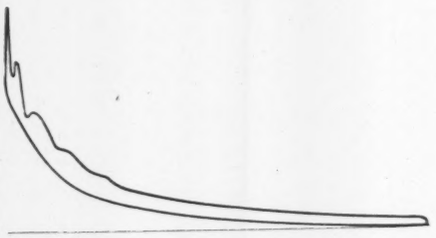


FIG. 6 QUARTER-LOAD DIAGRAM OF DOELLING ENGINE

sprays, and the combustion chamber used in the foregoing experiments. The air chamber and check for the storage of injection air from the main cylinder were not part of his solid-injection apparatus.

Fifteen years later James McKechnie (Vickers & Maxim) and his staff undertook exactly the same series of experiments. Today, as the result of McKechnie's work and that of other investigators, each of Diesel's solid-injection proposals is in commercial use. The problems encountered were two, namely, a delicate hydraulic and kinematic problem in handling small charges of oil at a rapid rate, and a problem of designing a piston which would serve as a vaporizer as well. McKechnie's earlier timed pump, accumulator (A), combustion chamber, and spray are shown schematically in Fig. 11.

The later "common rail" system with a pump M and a pressure main P serving mechanically operated sprays g is shown schematically in Fig. 12. This system is the basis of the Vickers, Atlas Imperial, and Enterprise engines.

It is natural that at first the production of injection air should be considered a handicap and an airless system a desirable attainment. Among the inventors seeking to avoid the use of a compressor Friedrich August Haselwander came into prominence in Germany about 1901. After a number of more or less futile proposals he finally formulated the following claim:

In an internal-combustion engine the use of a division wall or recess or the like adapted to co-act with the piston in such a way that shortly before the end of the stroke the space in front of the piston is divided into two parts in which the air or gas is compressed at different rates as the piston advances, while arrangements are provided whereby the escape of air or gas at higher pressure into the chamber containing air or gas at lower pressure is utilized to inject and mix the combustible with the air.

One such application is shown in Fig. 13. Oil is fed in at p^2 to meet the air streams. Even in its final form the principle was not effective but it held the imagination of many men.

In 1915 Jacob Gunther (Deutz-Otto) proposed the arrangement shown in Fig. 14, the oil entering at *g*. In 1916 he proposed that of Fig. 15, which was distinguished by both the point of injection and the conical neck and displacer. His engine later reached the commercial form shown in Fig. 16, in which the air jet is concentrated to oppose further advance of the spray, and a highly efficient and satisfactory motor resulted.

This incomplete historical sketch shows that oil-engine development, after the first basic proposals, was in reality not so much a problem in invention as a labor of acquisition of facts and figures necessary to determine the proper proportions and arrangement of the devices originally suggested. It is now in order to sum up the individual problems.

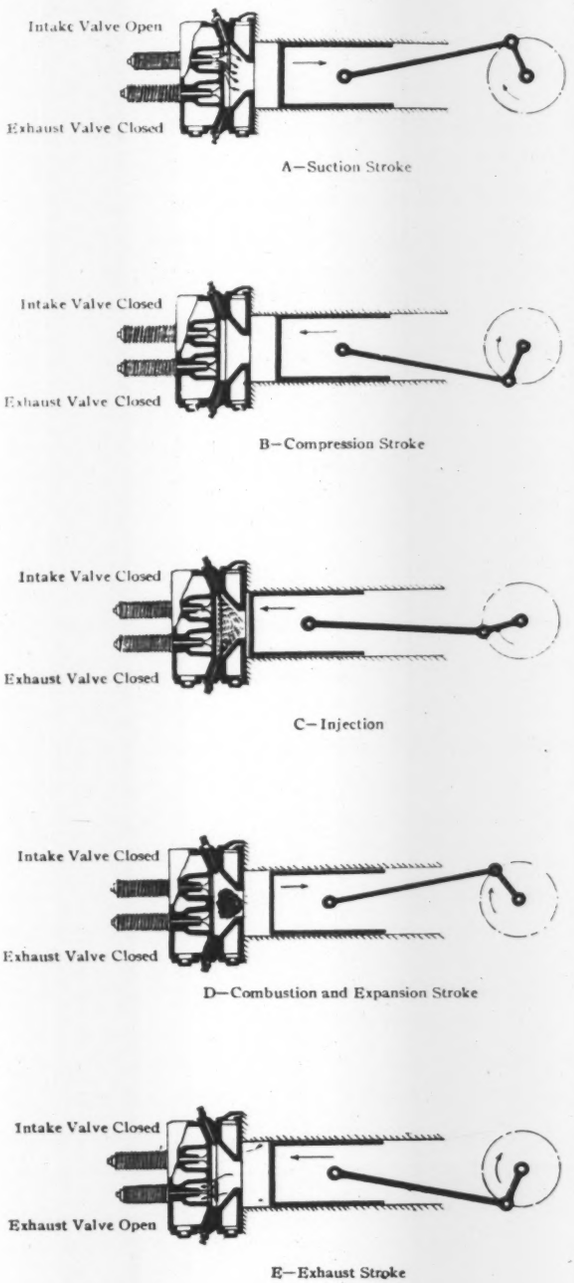


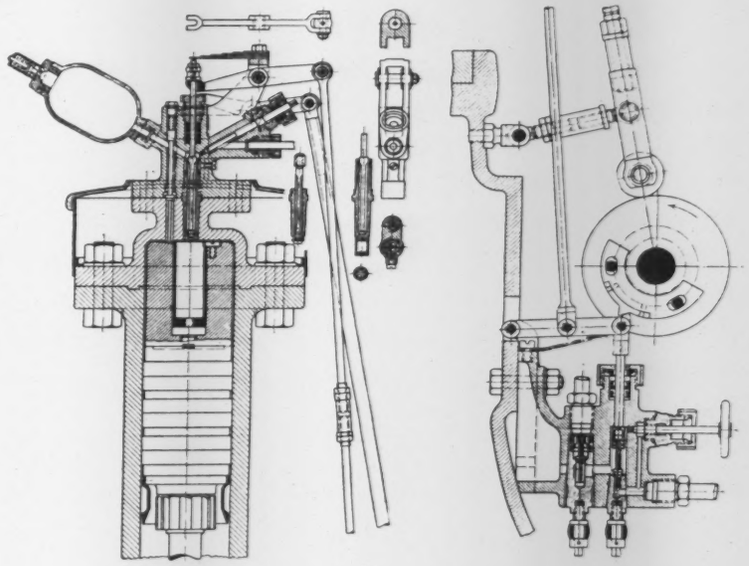
FIG. 8 WORKING CYCLE OF PRICE ENGINE

CRACKING

This phenomenon was known to refiners as early as 1861 and used as a process soon after, but the engine trade began to give it intelligent and practical consideration, as far as the author has been able to learn, as late as 1903. In that year William John Crossley and Wilfred Le Plastrier Webb in a patent application covering the use of water injection in their particular mode, stated that "any liquid or vaporized hydrocarbons which come into contact with the overheated parts of the vaporizer are thereby decomposed or partly decomposed, forming carbon or tarry deposits." Water injection was then used to limit the vaporizer temperature.

In early engines the hot surfaces were invariably too hot, but by the use of water injection at different rates and economy tests it was learned that best results were attained at vaporizer temperatures below red heat. The final investigations of the author were carried out with the aid of the cylinder head shown in Fig. 17. This head proved to be a valuable laboratory device. Its principle is the control of the hot-surface temperature by the vaporization of a liquid (mercury) in contact with that surface. Any excess of heat is dissipated by the rise of mercury vapor to the condenser on top of the pot. The condensate is returned to the well by gravity. By varying the pressure of air above the mercury, the boiling point of the liquid could be altered at will, and with it the temperature of the vaporizing surface. A thermoelement was staked into the bottom of the pot and led out to a pyrometer. Fuel economy and other characteristics were plotted against the hot-surface temperature. For a broad range of fuels the optimum temperature was very close to 850 deg. fahr. Above this the decline of desirable characteristics was rapid. Little change took place between 680 and 850 deg. fahr.

From these results valuable factors were deduced. Under the assumption that an overheated air charge due to excessive compression or incomplete scavenging would result in cracking of the fuel just as occurred with excessive vaporizer temperatures, limiting values for compression for various types of engines were estimated and successfully applied.[1]



FIGS. 9 AND 10 FUEL PUMP, VARIOUS SPRAYS, AND COMBUSTION CHAMBER USED IN DIESEL'S EXPERIMENTS

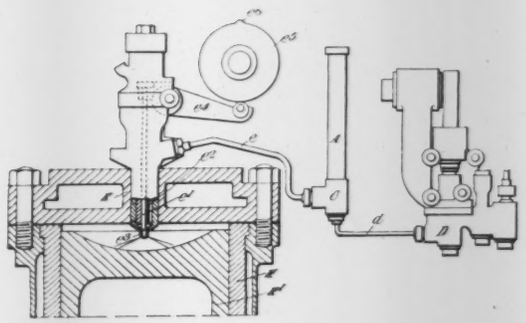


FIG. 11 MCKECHNIE'S EXPERIMENTAL ENGINE

[1] *Power*, vol. 57, p. 214.

CONDUCTIVITIES

At the A.S.M.E. Annual Meeting in December, 1915, Mr. Louis Illmer contributed a paper on oil-engine-vaporizer proportions.[1] This paper marked the passing of the Hornsby-Akroyd engine, but the section dealing with conductivities and the paths of heat flow remains most valuable in determining the hot walls of a

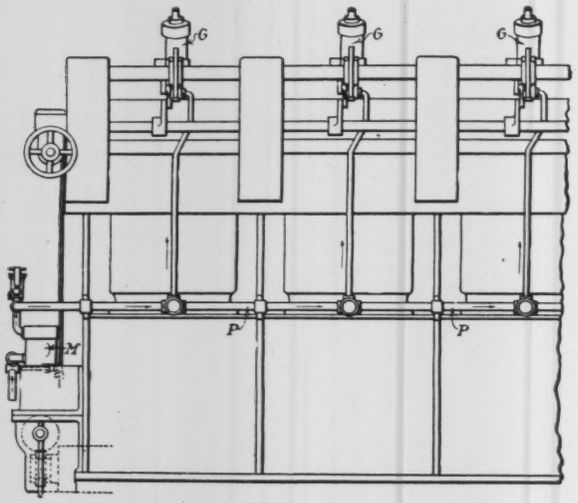


FIG. 12 COMMON-RAIL SYSTEM SERVING AS BASIS OF VICKERS, ATLAS, AND OTHER ENGINES

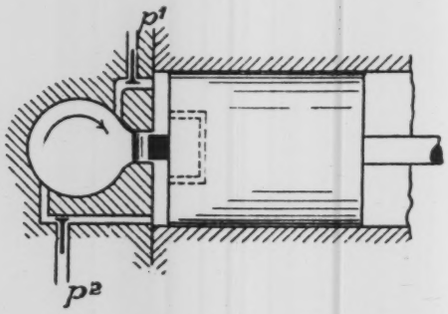


FIG. 13 HASELWANDER'S DIVISION WALL OR RECESS. OIL IS FED AT p^2 TO MEET THE AIR STREAMS

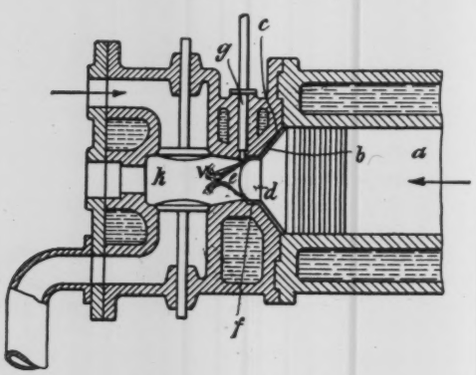


FIG. 14 GUNTHER'S ENGINE

combustion chamber within the temperature requirements. For example, in Par. 7 of this paper, Mr. Illmer states:

> The total temperature drop from the center to the edge of a thin disk (vaporizer) will equal the average drop per unit length multiplied by the disk radius, r, that is, for the disk

$$\theta = \theta_1 - \theta_0 \frac{1}{4} \frac{Hr^2}{KS}$$

where

θ_0 = temperature of disk at edge, deg. fahr.
θ_1 = temperature of disk at center, deg. fahr.
θ = $\theta_1 - \theta_0$ = temperature drop
K = specific thermal conductivity
H = uniformly distributed gross heat input in B.t.u. per hr. per sq. in. of area
S = thickness of disk.

[1] Trans. A.S.M.E., vol. 37, p. 845.

The external hot surface is now *passé*, but the piston head is a similar influence even in modern engines if the spray is directed against it and must be treated in the same way.

The actual value of H is quite difficult to determine, but it is always the same for the full-load condition of any given type of engine. K is fixed for any given material; θ is fixed by practical limits. As regards the variables r and S, it is the author's custom to fix S for one size by experiment and to vary it for the other sizes in the series according to r^2, thus solving the problem.

The Bristol Company made the author a contact thermocouple for use in this work. The engine is operated at full load until the

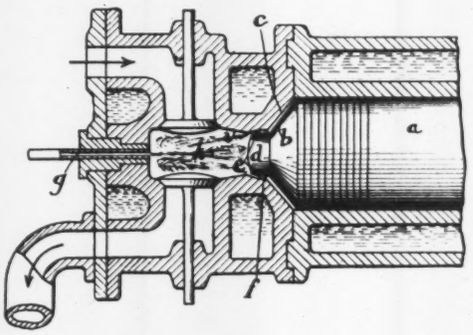


FIG. 15 GUNTHER'S ENGINE AS IMPROVED

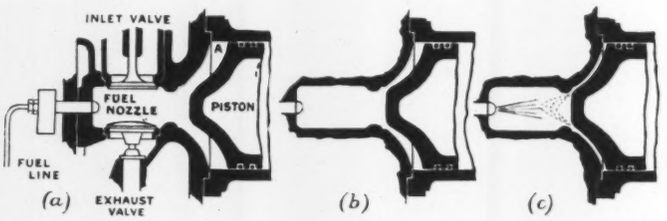


FIG. 16 GUNTHER'S ENGINE AS FINALLY BUILT
((a) Position of piston before air is partly trapped in ring-shaped space A. (b) Position of piston at start of air trapping. (c) Fuel injection at dead center into the air whorls.)

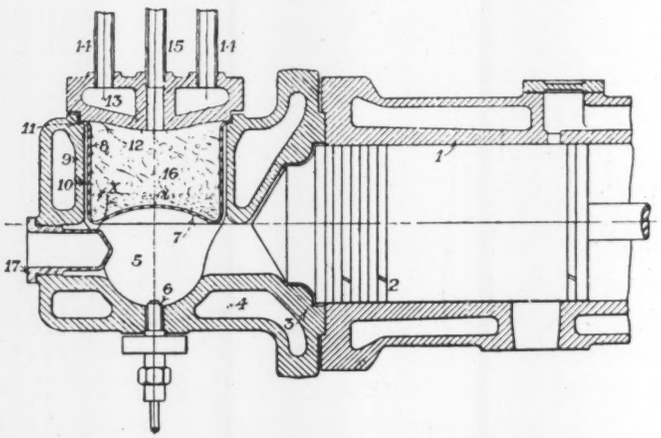


FIG. 17 EXPERIMENTAL HEAD USED BY AUTHOR
(In this head the hot-surface temperature is controlled by vaporization of a liquid in contact with the hot surface.)

exhaust temperature rises to a constant and fixed value signifying stable wall action. Preparation is made for a quick stop with the aid of the brake. A spray or valve is drawn in some fixed time, say, 30 sec., and the couple thrust against the piston surface. If the piston shows over 800 deg. fahr. it should be thickened. This applies to full-load operation. If the piston is too cold at light loads, some of the known means of compensation must be applied to increase the charge heat.

Realizing the importance of the piston-head temperature when

the spray strikes it, the Ljusne Woxna Aktiebolaget actually fixed a thermocouple in the piston of a crosshead engine and provided a swing connection to a millivoltmeter for piston-temperature readings in experimental operation.

A German patent (Paul H. Müller, No. 341,086, Sept. 11, 1920) describes an inspection opening created by the movement of the inlet valve while the engine is in operation, which is especially adapted to the observation of the piston when it serves as a hot surface. See Fig. 18. The author has had one such under test. The convenience of observation was accidental in the design but none the less real.

When the piston of a solid-injection engine serves as the vaporizer yet reaches such a size that cooling is required, a new application

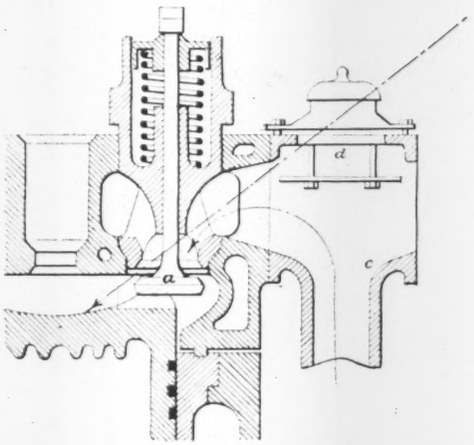


FIG. 18 INSPECTION OPENING DEVISED BY P. H. MULLER
(An opening *d* is provided in the inlet pipe *c* or the inlet-valve housing, through which the piston may be observed when the valve *a* is open.)

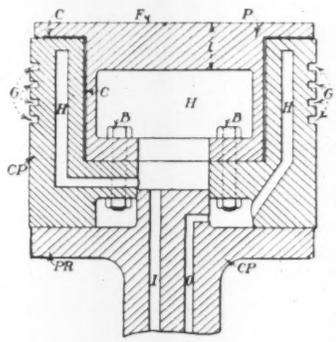


FIG. 19 KELLER'S SCHEME FOR COOLING PISTON SERVING AS VAPORIZER

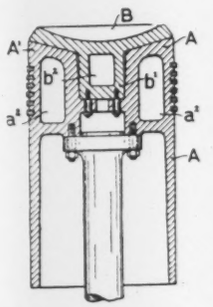


FIG. 20 REGENBOGEN'S SCHEME FOR COOLING PISTON SERVING AS VAPORIZER

of the principles of conductivity is made. Manifestly it is not feasible to spray against or along a jacketed piston wall any more than against a jacketed cylinder head. Accordingly a long path is provided for the heat flow from the piston-head surface to the piston jacket. Keller's scheme (Doxford) is shown in Fig. 19 and Regenbogen's (Krupp) in Fig. 20. Similar devices are found in true Diesel engines today.

FIG. 24 SPRAY-PIPE DIAGRAM

DETONATION

The solid-injection engine working at its best is never a Diesel-cycle engine but is a mixed-cycle engine. The explosion phase of the cycle serves to convey, disseminate, and intermix the clouds of vapor through the air.

Explosion is certainly a wave phenomenon, if not in the forced movement at least in the free movement before the restoration of equilibrium. The wave often shown on the indicator card is not a record of pressure, for if two or three springs are used in succession, waves of as many periods are recorded, and all agree with the natural period of the indicator motion for the spring in use.

The sound without the cylinder is certainly not transmitted from air waves within as there is no continuous medium. Various forms of cylinder heads give out various notes. Upon the sudden rise of pressure within, deflection takes place and then the walls vibrate until they come to rest. The piston has its own note, so also has the crankshaft. Low-pressure engines with very heavy reciprocating parts, crossheads, etc., may be in a state approaching balance between inertia and compression, and the slack and the oil film may take up violently. High-compression engines with reasonably light reciprocating parts may be as quiet as gas engines and still give mixed-cycle indicator diagrams.

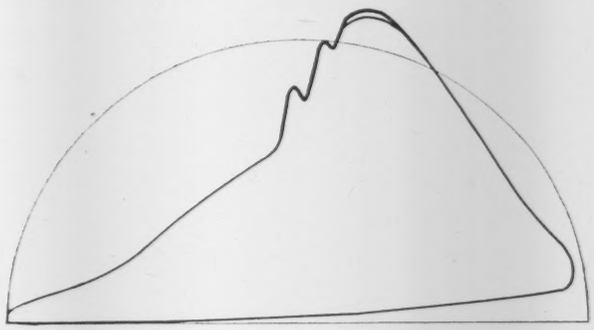


FIG. 21 RIGHT-ANGLE DIAGRAM FROM AN ENGINE BASED ON THE CROSSLEY PRINCIPLE

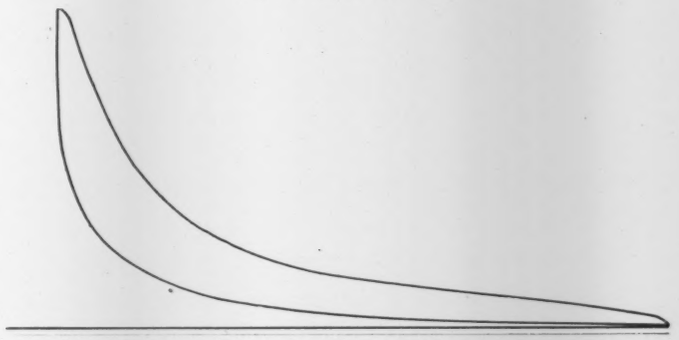


FIG. 22 INDICATOR DIAGRAM FROM A COMBUSTION CHAMBER LIKE THAT SHOWN IN FIG. 11

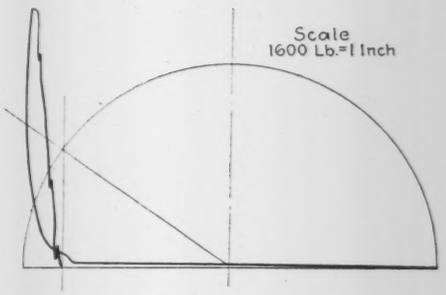


FIG. 23 DIAGRAM FOR MODERN HIGH-PRESSURE FUEL PUMP

Not only does the explosion appear to be necessary but the designer must consider the effect of the explosion upon the dissemination of vapor. If, in reacting to explosion, the vapor is forced into contact with cold walls without travel through the air charge, the results will be bad. The vapor cloud may be arrested centrally with some admixture of air and driven radially by the explosion to good advantage. The vapor cloud may be a cone with just enough air in its center to propel it outward through the air by a central explosion with excellent results.

Solid-injection engines today exhibit diagrams of most desirable characteristics. Fig. 21 is a right-angle diagram from an engine based on the Crossley principle. The pressure rise is by no means violent, yet it is smokeless. Fig. 22 is from a combustion chamber like that shown in Fig. 11 but with an automatic spray.

HYDRAULICS

The earliest fuel pump had every element of our present-day systems. The multiple-orifice spray was used with the early Hornsby-Akroyd engine. So also was the fuel bypass employed as a governing means. Yet these systems delivered fuel over a far longer interval than would be apparent from their mechanical timing.

The primitive diagram from a low-pressure pump handling a practically incompressible liquid is a rectangle. At present-day pressures of upward of 4000 lb. the elasticity of oil (about 0.00007 of the original volume per atmosphere) becomes a serious factor. The rise to pressure slopes, as also does the fall (Fig. 23). With an

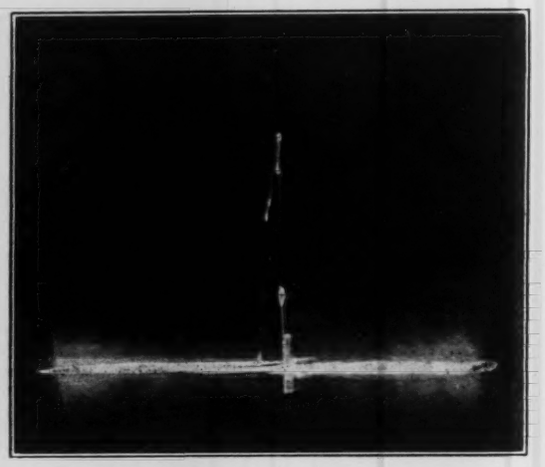


FIG. 25 PHOTOGRAPH OF NEEDLE MOVEMENT (MULTIPLIED) IN A MODERN HIGH-PRESSURE AUTOMATIC SPRAY VALVE

open spray an abrupt cam is necessary. With a spring-loaded spray the rise to lift pressure may be as gentle as desired.

If a suitably proportioned bypass is used, the release of pressure is rapid enough. If a variable-stroke pump is used without a bypass, the release of spray pressure through the open spray is subject to laws similar to those governing the emptying of a vessel through an orifice, the quantity of fuel discharged after cessation of pump travel being equal to the compression of the oil. The time of emptying in this case may exceed the time of an engine cycle. With a spring-loaded spray cessation of discharge follows the law of discharge from a standpipe between levels, i.e., a very high and attenuated standpipe. The spring-loaded automatic spray may be designed by proper selection of seat areas for a known "blowdown," say, 500 lb., and will thus close promptly and with very little discharge after cessation of pump movement, as shown by the spray-pipe diagram, Fig. 24.

Today it is customary to calculate the clearance in pump and delivery tube and spray, when the delivery due to elastic discharge at a known "blowdown" can be determined. This must always be less than the friction-load charge, of course, or a peculiar action will be set up, two or more pump deliveries being required to raise the pressure enough to lift the spray, after which the spray discharges the compressed volume and the operation is repeated. Such action, not uncommon, is avoided by proper consideration of the volume of oil acted upon relative to the required charge.

The hydraulic indicator is invaluable in investigating fuel-pump and spray phenomena. The indicator-piston displacement must be very small to avoid errors in deduction.

ATOMIZATION

In the solid-injection engine there is no means of producing an oil fog of such perfection as is produced by air injection. The minute drops of oil are not carried in on an energized vehicle, but must by virtue of their own mass and velocity carry from the nozzle to the desired location. In spray action, delivery accurate as to time, duration, and velocity is more important than atomization. Fig. 25 is a photographed record of the needle movement (much multiplied) in a modern high-pressure automatic spray valve. For promptness of action it leaves nothing to be desired.

PENETRATION

The preliminary development of sprays is usually carried out at the test bench with a power-driven pump. Here the penetration or carrying range of the spray is often a matter of feet rather than inches. This is particularly true of the multiple drilled-orifice sprays. The sprays with a single orifice and a spiral whorl to impart a rotary motion to the issuing jet, may be arranged to deliver a variety of profiles depending on the degree of rotary motion imparted by the tangent passages in the whorl and the diameter and length of orifice. This type of spray applies well to combustion chambers in which there is no hot surface, such as a hot plate or piston head, to halt the travel of the fuel. The centrifugal action may be made to absorb most of the energy of introduction. Its cone of distribution is too narrow for Diesel-type combustion chambers in which multiple-orifice sprays are generally used.

There is much argument as to whether the jets from high-pressure multiple-orifice sprays actually penetrate the dense atmosphere of the combustion space and reach the opposite wall. If the sprays are operated under water, a medium more dense and more viscous by far, it will be found usually that they are capable of penetration in that element exceeding the travel in the combustion space.

The author has caused the spray from a 0.012-in. orifice at 4000 lb. pressure to impinge upon the piston of a Hopkinson indicator at a distance of 3 in. and found that 89 per cent of its energy is recorded on the instrument. It is therefore almost true to Torricelli's law at short range. It would appear that it is still necessary to look to vaporization for success in solid-injection engines rather than to atomization, which for drilled sprays seems to be largely a surface effect.

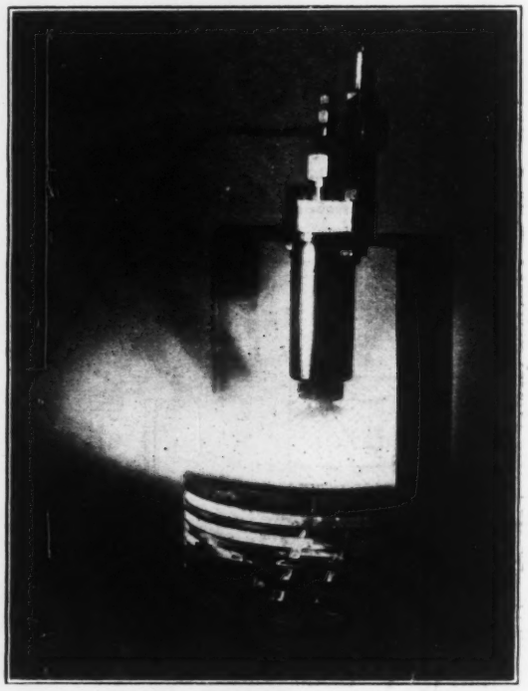


FIG. 26 MODERN SPRAY DISCHARGING AGAINST A PISTON HEAD HELD ARTIFICIALLY AT WORKING HEAT

Analysis of a number of recorded cases and of the author's own careful experiments on two high-pressure types seems to show that when the common arrangement of five spray holes is used in the tip, their diameter may be best determined by assuming a time of injection of, say, 0.01 sec. for moderate-speed engines and calculating the holes by the law $V = \sqrt{2gh}$, to which a suitable orifice coefficient is applied. Any attempt to atomize better by using smaller holes at any given pressure must only result in unduly extending the time of injection.

VAPORIZATION

It is the author's firm impression, checked by searching tests of no less than a dozen distinct and individual combustion-chamber

arrangements, that creating proper conditions for vaporization is one of the main functions of a solid-injection system. Fig. 26, from a photograph taken during the conduct of an extensive search into the properties of sprays at the shops of the Foos Gas Engine Company, shows a modern spray discharging against a piston head held artificially at working heat. The hot air charge has much the same effect on the spray. Diffusion of these vapor clouds could not take place in the time of a combustion interval, so dependence is placed upon explosion to do the mixing.

Any one who has ever distilled petroleum in an Engler flask knows that even the compression and hot-surface temperatures will not fully vaporize most fuels. At any rate to attempt to do so would result in cracking. The shattering effect of the explosion phase of the cycle undoubtedly atomizes the residues.

The terrific velocity of the jets acting in Fig. 11 results in vaporization far superior to that of the primitive hot-surface engine. The spray strikes at an angle of incidence which results in a scouring action, in imparting velocity to the vapor, and in a high rate of heat transfer to the fuel.

IGNITION

The combustion-chamber air or wall conditions must be maintained such that inflammation does not take place instantly upon injection. This momentary delay is aided by the incomplete state of compression at the beginning of injection and by the latent heat of vaporization of the fuel. If inflammation of the minute drops were to take place before their vaporization, the smoky flame of a body of oil burning upon the surface would naturally result.

TURBULENCE

Much inventive ability has been expended upon the artificial production of turbulence in the solid-injection engine. Engines of the Vickers type develop essentially the same economies as those fitted with displacers on the piston, etc. Differentiating the displacement of air through the neck between the cylinder and combustion space proper generally shows very low velocities. Even when the displacer is used as in the Crossley engine and the Gunther or Deutz-Otto type, the differential of pressure is low. In the engine shown in Fig. 15, it indicated only 10 and 12 lb. One is safe in saying that in Vickers-type combustion chambers (Fig. 11) artificial air turbulence in excess of that created naturally by induction has shown no improvement. In the Crossley type (Fig. 27) the annular air jet serves to prevent the spray from reaching the cold walls and to confine and return the vapors to the core of the charge prior to explosion. In the Deutz-Otto type (Fig. 16) it serves to check overtravel of spray to the hot displacer. In both of these latter it serves to bring up fresh supplies of hot air for the vaporization of fuel.

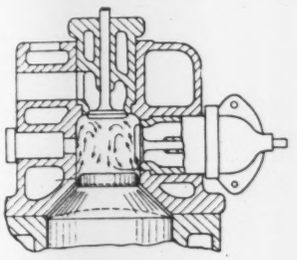


FIG. 27 CROSSLEY-TYPE COMBUSTION CHAMBER

The Hesselman case (Fig. 28) appears to be distinct, though opportunity has not yet been afforded to check it experimentally. Professor Hesselman reports marked improvement by the use of artificial means of creating turbulence, but the ultimate economy is not essentially better than in other engines of the same compression and spray pressure. It will be noted that the spray is directed to the circumference of the combustion chamber. Undoubtedly the explosion phase of the cycle is then not so efficient in scattering the vapors as it would be if the charge were more central and adapted to radial and outward dissemination through the unsaturated air by explosion. In this case rotary turbulence is undoubtedly of value.

When no hot surface is present, progressive movement of the heated air in the path of the spray is very important. The specific heat of air is low and the mass of the air charge is small. If the spray is merely suspended, conduction is slow. For proper vaporization, then, the air should be kept moving. There is little such movement in Fig. 11, where it is not required. In Fig. 8 the volume of air outside of the combustion chamber at the beginning of injection approximately equals that inside. By displacement the outer volume is moved up, bringing new supplies of heat.

CONCLUSION

The development of the solid-injection engine has suffered much by reason of the transmission of honestly proposed but fallacious theories of working. It has suffered, too, by a persistent desire to produce in an essentially individual type the characteristics of the air-injection Diesel. However, no single step in the development is without its contribution to the real theory of its working, and at this hour it would seem that the ultimate types have emerged from a seeming chaos of ideas to stand the test of time and progress.

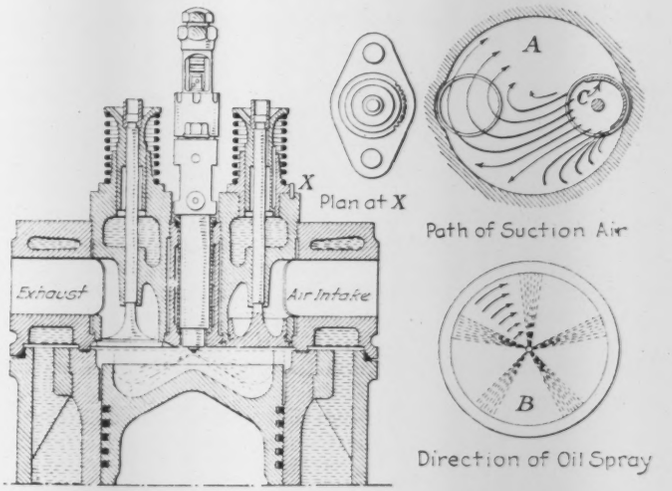


FIG. 28 COMBUSTION CHAMBER OF HESSELMAN ENGINE

Particular thanks are due Mr. S. F. Whitesel for his conscientious and painstaking assistance in the development of the evidences of spray action recorded in this paper, as well as for his photography.

Discussion

P. H. SCHWEITZER[1] submitted a written discussion in which he stated that the success of a solid-injection engine depended upon so many variables that one could not but wonder that the pioneer experimenters had attributed the failure of certain types to the failure of the principles involved rather than to some minor circumstances that were the real cause of failure.

The theories and opinions concerning combustion were far from being uniform. The Price engine was built with two spray nozzles opposite each other on the sides of the cylinder, with the idea of having the two sprays meet in the middle of the chamber and thus produce a good mixture and combustion. The engine was a success. Lately the Falk engine with a 19-in. bore had been built on this principle, and the company emphasized this action of breaking up the spray. The sprays had to travel $9\frac{1}{2}$ in. before meeting. Hesselman had calculated that an oil spray under similar conditions in compressed air did not penetrate more than $\frac{5}{8}$ in., irrespective of the initial oil pressure. He had built a successful engine on this principle, making the air to rotate in order to deliver the necessary oxygen particles to every oil particle. The author, as a result of his experiments in air and water, was of the opinion that the spray was able to penetrate a few inches at any rate. Mr. Schweitzer could not agree with him on the assumption that water offered more resistance than compressed air to the spray. Positive knowledge regarding the behavior of oil spray in compressed air should be obtained.

It was a fair assumption that *atomization* alone, if carried far enough, was sufficient to cause combustion. The true Diesel engine depended almost entirely on atomization. It had been observed that the preheating of the injection air caused detonation. In a solid-injection engine if the atomization was carried to this extent, using many small holes in the nozzle, the spray would not have the required energy to penetrate deep enough to meet the

[1] Asst. Prof., Engr. Research, Pa. State College, State College, Pa.

necessary number of oxygen particles. With more than five holes, unfavorable results were obtained. For the same reason the use of spiral grooves should be discouraged.

In the author's opinion, more dependence should be placed upon *vaporization*. At the German Diesel convention in 1923 Alt had expressed doubt concerning the part that vaporization played in combustion. His argument was that some oils had an ignition temperature many hundred degrees higher than their boiling point. The ignition temperature of some other oils was equal to, or somewhat below, the boiling point. If vaporization was essential for combustion, we should expect better combustion with oils whose ignition temperature was much above the boiling point since the oil globules then had more opportunity to mix. No such result had been obtained. While Alt had been dealing with the Diesel-type engine, the same reasoning could be applied, to a certain extent, to the solid-injection engine.

It was known that the ignition point was determined mainly by the temperature and that compression had little effect upon it. Tizard had advocated the theory that the ignition temperature was that at which the slow combustion of the fuel vapor with air evolved heat at a slightly greater rate than it was being dissipated by conduction. Hence ignition temperature depended on the rate of loss of heat and was different in turbulent air than in stagnant air. Experiments with and without fans showed differences in ignition temperature up to 120 deg. fahr. This checked with the observation that the ignition temperature in the engine was generally higher than that measured outside.

Indicator diagrams of solid-injection engines showed combustion of an explosive nature, and the author considered this advantageous and essential for the dissemination of vapor. Mr. Schweitzer, however, believed that a flatter combustion line would be desirable provided it would not lead to after-burning. A better control of the fuel injection as to spray action and accurate delivery in quantity and timing might lead to this end.

There might be some doubt regarding the author's contention that an ordinary explosion was a wave phenomenon. The waves of indicator cards, as he remarked, showed different frequencies for different stiffnesses of springs. Cards taken from airplane engines, with refined methods, showed rapid explosions but no waves. The indicators now in general use were not adapted to explosive engines, even for speeds not exceeding 500 r.p.m.

It was difficult to agree with the author that the external hot-surface was now *passé*. A successful low-pressure engine recently developed by the Venn-Severin Machine Company had an uncooled ring between the cylinder and head. The axial spray, which had an adjustable cone angle, struck this external hot ring at starting, but after the engine became warm, the spray cone closed and no longer impinged upon the hot surface.

P. P. Bourne[1] wrote that the section of the paper entitled Detonation was especially interesting as dealing with phenomena existing in what the author called "mixed-cycle" engines. It was generally understood that in this type of engine the pressure rose considerably during combustion, this rise being approximately equal to one-half the combustion pressure. Some of the better-known engines of this class were the Vickers, Crossley, Deutz, and engines built according to Price, such as the De La Vergne and Ingersoll-Rand. With such combustion the engine did not work upon the Diesel cycle, but the combustion more nearly corresponded to that of the explosive cycle. The high combustion pressure was taken care of in the design by providing parts with the necessary additional strength. However, this type of engine worked under the disadvantage referred to by the author as a tendency to produce a detonation which imposed shock on the structure. It was undeniable that it was desirable to avoid this by obtaining a true Diesel cycle by solid injection.

Mr. Bourne agreed in general with the author's statements concerning detonation, but took exception to the statement that the solid-injection engine, working at its best, was never a Diesel cycle engine, but a mixed-cycle one. One type of engine was built which worked on a true Diesel cycle with solid injection. This engine used what might be described as two-stage combustion, and the type in most common use in the United States was that developed and manufactured by the Worthington Pump & Machinery Corporation.

The construction, as shown in Fig. 29, indicated the combustion method. Direct pump injection was used at an oil pressure of not over 1000 lb. per sq. in. The fuel was injected into a precombustion chamber, where some of the oil was partially burned. The pressure rise in this chamber produced a pressure differential above the combustion pressure in the cylinder or combustion chamber proper, which caused the flow of a charge of burning fuel and gas into the cylinder at a rate sufficiently slow to produce the same combustion conditions in the cylinder as would exist in an air-injection Diesel engine. Fig. 30 showed a characteristic indicator card taken from an engine of this general type.

The construction of the cylinder head was such that all parts of the combustion and precombustion chambers, as well as the sprayer,

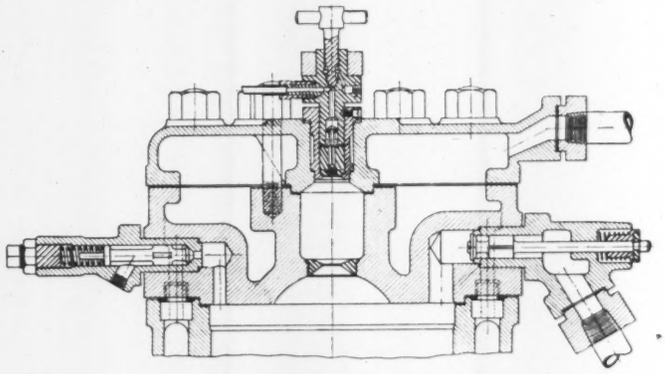


FIG. 29 CYLINDER-HEAD CONSTRUCTION OF TWO-STAGE COMBUSTION TYPE OF ENGINE

were thoroughly cooled. The piston might be cooled to any extent desired without interfering with perfect performance. The larger sizes were fitted with oil-cooled pistons which worked well in spite of the difficulty described by the author in a statement that it was not feasible to spray against or along a jacketed piston wall any more than against a jacketed cylinder head, probably because the fuel in this case was not in liquid form.

In this type of engine the distribution of the fuel through the

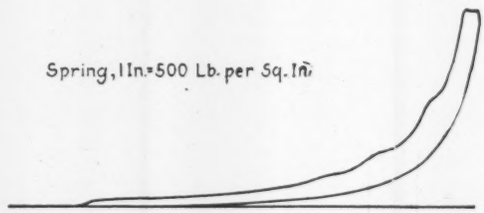


FIG. 30 TYPICAL INDICATOR CARD FROM TWO-STAGE COMBUSTION TYPE OF ENGINE

air in the combustion chamber was attained by utilizing the high velocity of the gases through the throat between the two combustion chambers. Hence it was unnecessary to impart extreme energy to the fuel by injection at high pressure, and a simple form of injection apparatus became possible. The fuel consumption averages 0.33 lb. per i.hp-hr. The low injection pressure allowed larger holes to be used in the spray nozzle, so that this was less delicate than would be otherwise possible. The openings were less likely to clog in operation, especially as the tip could not become overheated.

Louis Illmer,[1] in a written discussion, said that the subject of fuel pumps might have been stressed to a greater extent in the paper. This accessory constituted the heart of the direct-injection oil engine and represented the primary means of controlling the combustion process. Certain figures were given by the author relating to the elasticity of fuel oil, but no mention was made of the fact that the air entrained in the liquid might produce disturbances in pump action that would far exceed those resulting from elasticity

(*Continued on page 278*)

[1] Ch. Engr., Worthington Pump & Mchy. Corp., East Cambridge, Mass. Mem. A.S.M.E.

[1] Research Engr., Lansdowne, Pa. Mem. A.S.M.E.

Reheating in Central Stations

By W. J. WOHLENBERG,[1] NEW HAVEN, CONN.

In this paper the author discusses the influence of amounts of energy added in reheating, number of reheating stages, and points in expansion at which reheating should begin. A comparison is made of reheating, regenerative, and combination cycles combining both reheating and bleeding stages, and it is shown that, because of the influence on the internal machine efficiency thereby, reheating properly applied may lead to higher efficiencies than bleeding. It is furthermore shown that the combination cycles give promise of realization in practice of appreciably higher efficiencies than would be the case for the other cycles investigated. The analysis also indicates that for a limiting steam temperature of 750 deg. fahr. the maximum efficiency is attained at initial pressures varying between 600 and 900 lb., the exact optimum depending upon cycle, fuel, and steam generator used; and that if pressures are increased beyond these points there will result an actual reduction in overall efficiency.

THIS paper is first occupied with an attempt to discover the proper place of reheating in the central station on an ideal basis. Secondly, modifications of ideal conditions leading to expected practical performance are introduced.

The Reheating Cycle

This cycle is illustrated on the temperature-entropy diagram in Fig. 1. The reheating in this particular diagram is performed in two stages with an expansion *GI* between them. The gain of work is equal to *EGIJLMN*, and the energy added, to *EGIJKF*. In a one-stage reheating cycle, the diagram would of course end with the vertical line *GMH*, with the point *M* as the final point of the cycle. It is obvious that the work area *EGIJ* for a given width *JI* increases as point *E* is raised. The most efficient condition will therefore result by continuing the superheat beyond point *D*. In practice, however, available materials limit this point to about 750 deg. fahr., and in this analysis upper steam temperatures of 750 deg. fahr. will be considered as the limit of good design, with 1000 deg. fahr. as a possible coming future standard.

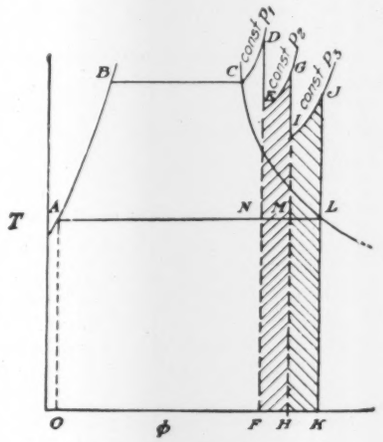


Fig. 1 Two-Stage Reheating Cycle

Effect on Efficiency of Reheating Point, Number of Stages, and Amount of Reheating

One-, two- and three-stage cycles have been investigated. The solution of the problem is most readily accomplished by means of the Mollier chart.[2]

Figs. 2 and 3 represent respectively the influence of number of stages and quantity of energy added on the cycle efficiency. The following conclusions may be drawn:

a There is an appreciable gain in efficiency of the two-stage cycle over the one-stage cycle, but beyond two stages very little gain may be expected.

b For each cycle there is an optimum energy quantity per stage which varies slightly with initial pressure and considerably with initial temperature.

c The maximum efficiency increases considerably with pressure and still more with temperature. (See curve 7, Fig. 3.)

d The optimum cycle efficiencies are materially better than those of the Rankine cycle for a given initial steam temperature.

Bleeding vs. Reheating Cycles

Fig. 4 represents a typical two-stage bleeding cycle on the temperature-entropy diagram. The saturation line is represented by *CFMGHC″*. Quality curves would be symmetrical with the saturation lines. The sharp breaks to the left are caused by the depletion in total-steam quantities at bleeding points. For every pound of steam entering the turbine only a fraction of a pound, due to bleeding, is exhausted, but the quality variations in the expansion following bleeding are just as if no bleeding had taken place. The points at which the steam condition crosses the saturation line are indicated respectively by *N* and *N′* for the bleeding and non-bleeding or Rankine cycles.

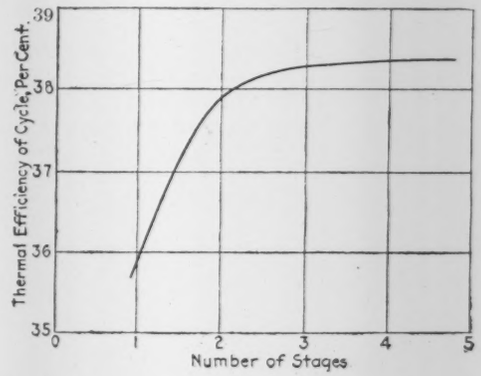


Fig. 2 Influence of Number of Stages in Reheating Cycle
(300 lb., 750 deg. fahr., 1 in. Hg; total reheat, 300 B.t.u.)

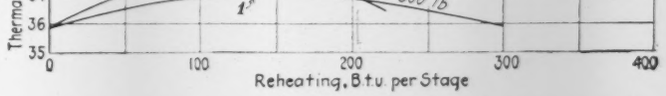


Fig. 3 Influence of Amount of Reheating on Cycle Efficiency
(Reheat in each stage carried back to initial heat content of steam.)
Curves 1, 2, 3: Single-stage reheating, 750 deg. fahr. steam temperature.
Curves 4, 5, 6: Two-stage reheating, 750 deg. fahr. steam temperature.
Curve 7: Single-stage reheating, 1000 deg. fahr. steam temperature.

One- and two-stage cycles are considered, in the first of which feedwater is heated from condensate temperature at 240 deg. fahr., and in the second, first to 180 deg. fahr. and then to 280 deg. fahr. A solution for efficiency is conveniently made with the aid of the Mollier chart.[1]

The results are represented by Curves *D* and *E* of Fig. 5. Curves *B* and *C* show efficiencies of one- and two-stage reheating cycles for the optimum reheat quantities shown in Fig. 3. From these it is obvious that ideal bleeding cycles are more efficient than the best ideal reheating cycles. It may therefore be found advantageous to combine the reheating and bleeding processes in the same machine. The bleeding process improves the efficiency by transferring energy within the cycle, and the reheating process properly used adds energy where its availability for work is high. In addition, reheating, as later shown, is the means of materially improving the internal machine efficiency of the prime mover.

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[1] Assistant Professor of Mechanical Engineering, Sheffield Scientific School, Yale University. Assoc-Mem. A.S.M.E.

[2] Formulas and methods given in Appendix No. 1 to the complete paper.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

[1] Formulas and methods given in Appendix No. 2 to the complete paper.

COMBINATION CYCLES

In Fig. 6 the *RBRB*-cycle indicates one composed of two bleeding stages with two reheatings incorporated between them. Various combinations may be investigated, but from data now available the most favorable reheating and bleeding conditions may be chosen. They are as follows:

One-Stage Reheating: 140 B.t.u. to occur in the cycle after a 140-B.t.u. drop in the expansion line. (See Fig. 3.)

Two-Stage Reheating: 120 B.t.u. per stage occurring alternately with expansion after successive 120-B.t.u. drops in expansion line. (See Fig. 3.)

One-Stage Bleeding: Condensate raised to 240 deg. fahr. temperature. Pressure = 25 lb. abs.

Two-Stage Bleeding: Condensate raised first to 180 deg. fahr. and then to 280 deg. fahr. Bleeding pressures, 7.5 in. Hg and 49 lb. abs.

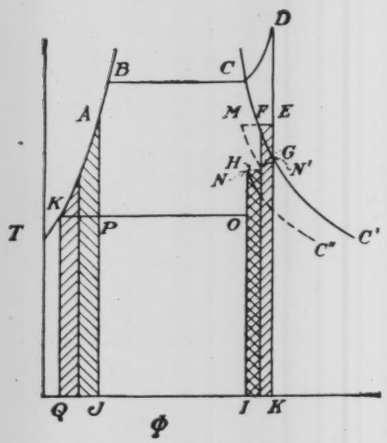


FIG. 4 TWO-STAGE BLEEDING CYCLE

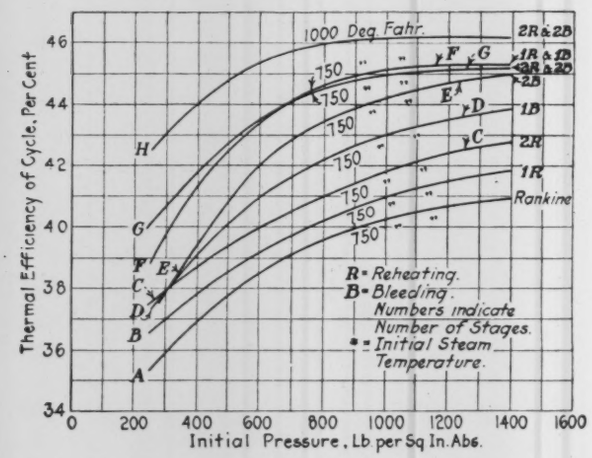


FIG. 5 EFFICIENCIES OF VARIOUS REHEATING AND OTHER CYCLES

Steam conditions, *A* to *F*, inclusive: Initial temperature, 750 deg. fahr.; back pressure 1 in. Hg.
Steam conditions for curve *H:* Initial temperature, 1000 deg. fahr.; back pressure, 1 in. Hg.
Bleeding points: 240 deg. fahr. or 25 lb. in one-stage bleeding cycles.
280 and 180 deg. fahr. or 50 lb. and 7.5 in. Hg in two-stage cycles

These conditions apply for an initial steam temperature of 750 deg. fahr. When this is increased to 1000 deg. fahr. the energy added in reheating is increased to 250 and 200 B.t.u. per stage, respectively, for the one- and two-stage cycles.

A fulfilment of these fundamental conditions may lead to a change in order of the reheating-bleeding processes as the pressure range is followed through. This *R-B* order will, however, be left to appear as it happens to be fixed by the above more important considerations. In solving the problems the Mollier chart again comes into play.[1]

The resulting variations in efficiency are shown by curves *G*, *F*, and *H* in Fig. 5, from which the following conclusions may be drawn:

a Combination cycles are considerably more efficient than the other cycles investigated.

b The ideal efficiency increases rapidly as pressures increase, but beyond 1000 lb. little is to be gained.

c An increase in initial temperature very materially increases the efficiency.

[1] Formulas and methods given in Appendix No. 3 to the complete paper.

The next phase of the problem naturally has to do with relating of ideal and actual performances. This involves the influence of the various processes on the internal machine efficiencies of the prime movers.

THE INTERNAL MACHINE EFFICIENCY

The thermal efficiency of the actual internal work will be equal to the product

$$E_c \times E_i$$

in which E_c is the thermal efficiency of the cycle and E_i the internal machine efficiency. The above product times E_m, the mechanical efficiency, will result in the overall efficiency of work at the shaft based on the heat energy absorbed by the working medium. The efficiency product $E_i \times E_m$ involves the following losses:

a Nozzle and blade frictional losses
b Leakage and disk friction
c Gland, bearing, and governor friction
d Radiation.

The first two of these determine E_i and the fourth may be included with the third as part of the loss involved in E_m. Under these conditions E_m may be taken at 99 per cent without appreciable error for the cases investigated.

A detailed determination of E_i throughout the turbine involves factors known only to the turbine designer, but its mean value may be computed from test results. These with proper corrections may be applied to the conditions of the problem. Correction factors for superheat, pressure, and vacuum have been fairly well established for the usual operating cycles, but how to apply steam-temperature corrections in reheating cycles is at first glance somewhat of a puzzle. For such cases the initial steam condition is

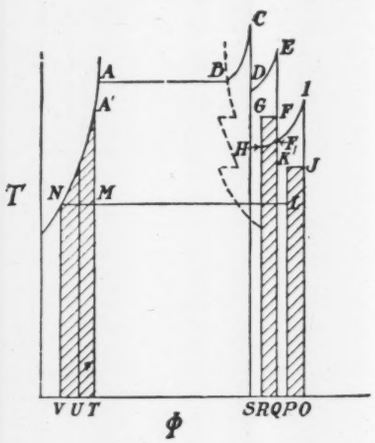


FIG. 6 *RBRB*-CYCLE

Energy available for work = *A'ABCDEFGHIJKLNA.*
Net heat added = *A'ABCDEFF'IOTA'* + *HF'QRH.*
Shaded areas represent heat transferred by bleeding.
Reheat = *SDEQ* + *RHIO*

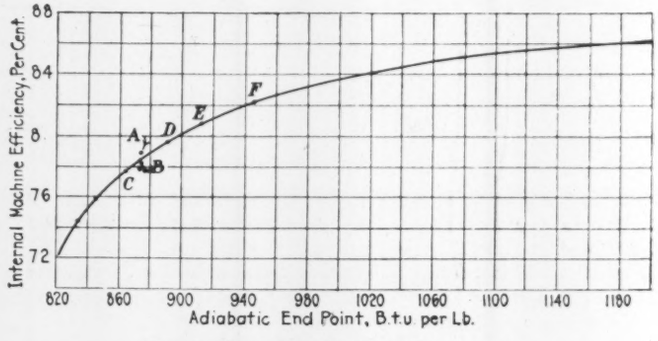


FIG. 7 INTERNAL MACHINE EFFICIENCY

A—60,000-kw. 3-cyl. Westinghouse compound.
B—30,000-kw. single cylinder G. E.
C, D, E, F—30,000-kw. Westinghouse compound. Back pressure, 1 in. Hg.

no longer indicative of its mean condition throughout the turbine, and this, for a given turbine, is the primary factor in evaluating losses (*a*) and (*b*) above.

However, for a given back pressure the adiabatic end point of the expansion process is a sort of integrated value of the steam condition throughout, particularly if the reheating has occurred, as it should have, early in the cycle. Such end points can always be found by tracing out the ideal cycle on the Mollier chart. If for a machine under consideration test data are available, actual internal machine efficiencies may be plotted against adiabatic end

points for a given back pressure. Fig. 7 represents such a curve plotted by means of test data available for a number of large turbines as indicated.[1]

THERMAL EFFICIENCY AT SHAFT BASED ON HEAT ABSORBED

The end-point heat contents and internal machine efficiencies for the cycles and conditions considered are given in Table 1.

TABLE 1 END-POINT HEAT CONTENTS AND INTERNAL MACHINE EFFICIENCIES FOR VARIOUS CYCLES AND CONDITIONS

(Heat contents in B.t.u.; efficiencies in per cent.)

Initial	Rankine and Bleeding Cycles 750 deg. fahr.		One-Stage Reheating 750 deg. fahr.		Two-Stage Reheating 750 deg. fahr.		Two-Stage Reheating 1000 deg. fahr	
Pressure, lb.	End Pt.	Mach. Effy.	End Pt.	Mach. Effy.	End Pt.	Mach. Effy.	End Pt.	Mach. Effy.
300	912	80.8	983	83.4	1035	84.5	1145	85.8
600	865	77.8	940	82.0	989	83.5	1110	85.3
1200	818	71.8	890	79.6	943	82.2	1102	85.2

Reference to this table brings out the following conditions:

a Unless reheating is used the machine efficiency is relatively low at high pressures.

b With 1000-deg. fahr. steam temperature the machine efficiency is 3 per cent better for two-stage reheating at 1200 lb. pressure than it is with 750 deg. fahr. steam temperature.

The thermal efficiencies at the shaft based on heat absorbed are represented in Fig. 8. The following conditions are apparent:

a Because of its effect on machine efficiency, reheating becomes more efficient than bleeding.

b The highest efficiency is obtained in the two-stage combination cycle, i.e., $2R$ and $2B$.

c All curves shown have maximum points and for 750-deg. fahr. steam these are in most cases below 1000 lb. pressure.

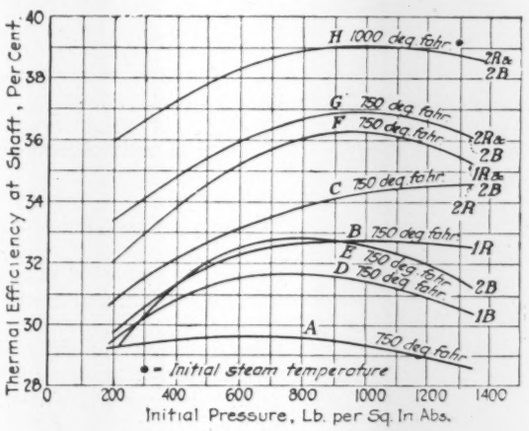


FIG. 8 THERMAL EFFICIENCIES AT SHAFT BASED ON HEAT ABSORBED

The fact that steam generators naturally fall off in efficiency with increasing pressures will tend to throw the high-efficiency points still farther down the pressure scale.

THE STEAM GENERATOR IN REHEATING STATIONS

Reheating surface will normally be included within the boiler setting to withdraw heat from the products of combustion. Mean steam temperatures within them will be somewhat higher than boiler-surface temperatures for 300-lb. and 600-lb. pressures, but for 1200-lb. stations they will actually be somewhat lower. The pressures existing within the reheaters will be considerably below those existing in the boilers, as shown in Table 2. It appears,

TABLE 2 REHEATER PRESSURES FOR VARIOUS BOILER PRESSURES

(Pressures in lb. per sq. in.)

Initial Pressure	Reheater Pressures: One Stage	Two Stages: 1st Stage	Two Stages: 2nd Stage
300	88	105	46
600	170	210	70
1200	290	380	120

therefore, that for a given heat absorption, reheater surface advantageously placed may not be more expensive than boiler surface. This would be particularly true if the reheating surface should be exposed directly to furnace radiation, as under these conditions the rate of heat absorption would be very high. Such an arrangement also has obvious advantages when considering maintenance of furnace walls and should lead to higher steam-generator efficiencies because a larger proportion of the total liberated heat energy may be absorbed in the furnace, leaving, therefore, less energy to be absorbed by convection. The reheater maintenance may, however, be high and there are some operating disadvantages which may make the arrangement undesirable, particularly at light loads when the reheating would be excessive.

[1] Data and computations given in Appendix No. 4 to the complete paper.

STEAM-GENERATOR EFFICIENCIES

For high pressures boiler-surface temperatures will be increased with a corresponding rise in the escaping-gas temperature. Econ-

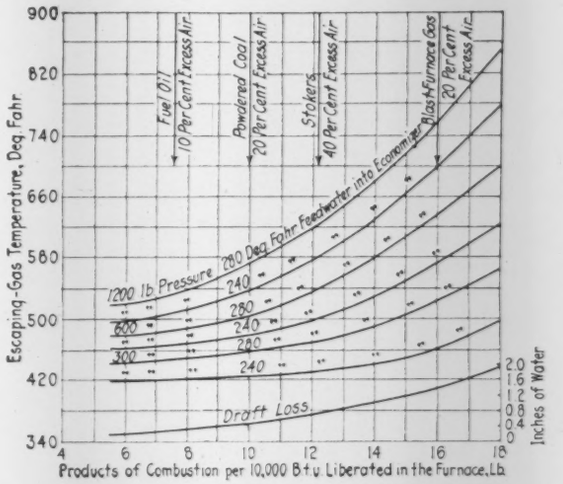

Escaping-Gas Temperature, Deg. Fahr
Products of Combustion per 10,000 B.t.u. Liberated in the Furnace, Lb.
Inches of Water
Fuel Oil 10 Per Cent Excess Air
Powdered Coal 20 Per Cent Excess Air
Stokers 40 Per Cent Excess Air
20 Per Cent Excess Air
280 Deg. Fahr. Feedwater into Economizer
Blast-Furnace Gas
1200 lb. Pressure
600
300
240
Draft Loss

FIG. 9 STEAM GENERATORS. RELATION BETWEEN ESCAPING-GAS TEMPERATURES AND PRODUCTS OF COMBUSTION PER 10,000 B.T.U. LIBERATED IN THE FURNACE

(Steam temperature, 750 deg. fahr. One-third of total surface in economizer one-pass gas flow; average rate of heat absorption, 5000 B.t.u. per sq. ft. per hr.)

omizer surface will, due to high feedwater temperatures, absorb less heat in two-stage than in one-stage bleeding stations. These conditions together with the influence of combustion on escaping-gas temperatures are shown in Fig. 9.

The expected efficiencies for a stoker-fired plant with a steam generator proportioned as shown and absorbing heat at the average rate of 5000 B.t.u. per sq. ft. per hr. are stated in Table 3.

TABLE 3 STEAM-GENERATOR EFFICIENCIES FOR VARIOUS CYCLES AND PRESSURES

Steam pressure, lb. per sq. in.		300	600	1200
One-Stage Bleeding	Escaping-gas temperature, deg. fahr.	430	500	580
	Combined efficiency, per cent	82.8	80.8	78.4
Two-Stage Bleeding	Escaping-gas temperature, deg. fahr.	470	540	620
	Combined efficiency, per cent	81.8	79.8	77.8
Rankine	Efficiency, per cent (90 deg. fahr. feedwater)	85.2	83.2	80.8

OVERALL EFFICIENCIES FOR A GIVEN STEAM-GENERATING PLANT

Curves *D*, *E*, *F*, *G*, and *H*, Fig. 10, represent the overall efficiencies by combining the foregoing steam-generator efficiencies with those from Fig. 8. The economies in B.t.u. per kw-hr. for certain of these stations are shown by curves *F*, *G*, and *H* of Fig. 11. It is apparent from these curves that no gain may be expected by increasing pressures beyond 850 lb.

STATIONS OF MAXIMUM EFFICIENCY

When high load factor and cost of fuel make feasible the use of steam generators of exceedingly high efficiencies, the following modifications may be made:

a Decreased average rate of heat absorption

b Increased ratio of economizer to boiler surface

c Installation of air preheaters

d Burning coal in powdered form.

Under these conditions average steam-generator efficiencies of 86 to 90 per cent may be realized even for the high-pressure two

stage-bleeding stations, but to accomplish efficiencies appreciably higher than this even in the low-pressure stations would undoubtedly involve prohibitive conditions.

For a steam-generator efficiency of 88 per cent a new set of efficiency and economy curves represented by F', G' and H' in Figs. 10 and 11 are arrived at. Reference to them indicates that for 750-deg. steam the maximum-efficiency point occurs at 1000 lb. pressure. The efficiency has a value of 32.3 per cent and the economy is 10,300 B.t.u. per kw-hr. at the turbine shaft. Generator losses, power for auxiliaries, and pipe-line radiation have not

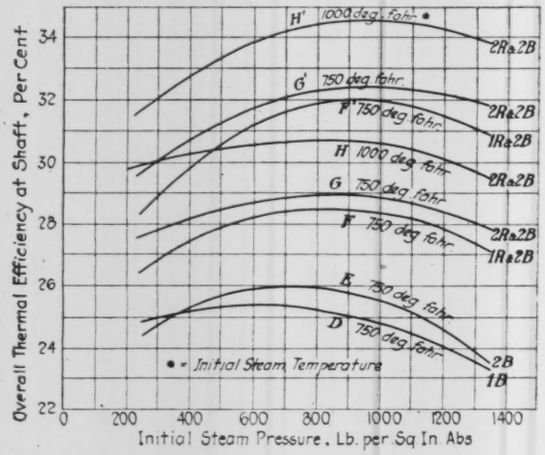
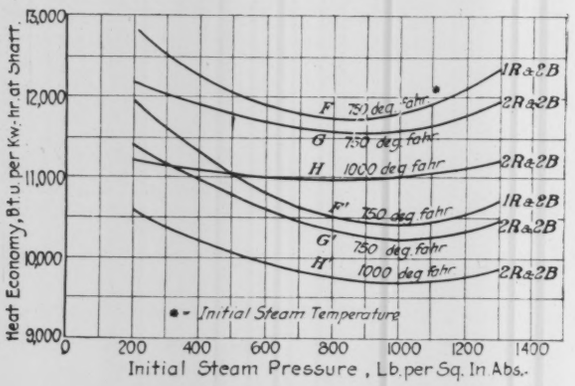


Fig. 10 Overall Thermal Efficiencies of a Given Steam-Generating Plant for Various Combination and Bleeding Cycles

(Auxiliaries, electric generator and pipe-line radiation losses not included.)
Curves D, E, F, G, and H for a stoker-fired plant.
Curves F', G', and H' for a powdered-coal maximum-efficiency plant in which steam-generator efficiency is 88 per cent.


Heat Economy, B.t.u. per Kw.-hr. at Shaft
Initial Steam Pressure, Lb. per Sq. In. Abs.
F 750 deg. fahr. *
G 750 deg. fahr.
H 1000 deg. fahr.
F' 750 deg. fahr.
G' 750 deg. fahr.
H' 1000 deg. fahr.
* = Initial Steam Temperature
1R&2B
2R&2B

[Fig. 11 Overall Economies for Stations Employing Various Combination Cycles

(Auxiliaries, electric generator and pipe-line radiation losses not included.)
Curves F, G, and H for stoker-fired plants.
Curves F', G', and H' for high-efficiency powdered-coal plants in which steam-generator efficiency is 88 per cent.

been included. If 10 per cent is charged to these three items the net results are as follows:

Net overall efficiency = 29.1 per cent

Net economy = 11,500 B.t.u. per kw-hr. at the switchboard.

We may conclude that the station with a net overall economy of 12,000 B.t.u. is in sight. Its characteristics and principal dimensions may be about as follows:

Initial steam pressure, 900 to 950 lb. per sq. in.
Initial steam temperature, 750 deg. fahr.
Back pressure, 1 in. Hg.
Steam Cycle: Combination $2R + 2B$.
Reheating, 120 B.t.u. per stage per lb.
Bleeding, 49 lb. and 7.5 in. Hg.
Condensate, 280 deg. fahr. and 180 deg. fahr.
Steam Generator:
Surface equally distributed between boiler and economizer.
Average rate of heat absorption, 3000 B.t.u. per sq. ft. per hr.
Air-preheater surface per sq. ft. of surface in boiler and economizer, 0.2 sq. ft.

Boiler, superheater, and economizer surface per kw. $= \frac{12{,}000}{3000} \times 0.88 = 3.52$ sq. ft.

Boiler, superheater, and economizer surface corrected for reheating per kw. $= \frac{1345 - 248}{1345 - 248 + 240} \times 3.52 = 2.89$ sq. ft.

Reheating surface per kw. = (?) depends on position.
Energy absorbed in reheater per kw-hr. = 1900 B.t.u. = 18 per cent of total.
Air-preheater surface per kw. = $0.2 \times 3.52 = 0.70$ sq. ft.
Temperature of gases escaping from boiler, 620 deg. fahr.
Temperature of gases escaping from economizer, 350 deg. fahr.
Temperature of gases escaping from air preheater, 260 deg. fahr.
Draft loss in boiler and economizer, 1 in. water.
Draft loss in air preheater, 4 to 5 in. water.
Fuel: Powdered coal burned with 20 per cent excess air.

Conclusions

The following conclusions may be drawn from what has been presented:

a With increasing pressures and a limited steam temperature, reheating is becoming essential for lightest efficiencies.

b The introduction of reheating stages does not operate to make bleeding stages less beneficial, and in the future stations both bleeding and reheating stages will probably be incorporated in the steam cycle.

c Under present limiting conditions as to steam temperature there is little to be gained by using more than two reheating stages.

d Reheating should be accomplished as early in the expansion period as possible.

e For variable-load operation the reheating coils should preferably be placed in the gas-convection path screened from direct furnace radiation and the load on the steam generators maintained proportional to that of the prime movers.

f For stoker-fired plants using the combination cycle material gains in economy should result by increasing pressures up to between 700 and 800 lb., but beyond this point no apparent gains exist.

g In powdered-fuel plants using the combination cycle material gains in economy may be expected by increasing pressures up to 900 lb., but beyond this point no apparent gains exist.

h To increase pressures materially above points noted in (*b*) and (*g*) will apparently result in an actual reduction of economy for the conditions stated.

i For properly designed stoker-fired plants operating on the combination cycle at optimum conditions, economies of 13,000 B.t.u. are apparently in sight.

j For properly designed powdered-fuel plants operating under optimum conditions, economies of 12,000 B.t.u. and better appear possible.

k Future improvements in turbine design may slightly influence optimum pressures. Such improvements will, however, probably lead to a proportional shift in the internal-machine-efficiency curve, resulting merely in a higher efficiency at nearly the same optimum pressure.

l More accurate information on the properties of high-pressure steam may lead to a readjustment of optimum pressures for the conditions stated. It is thought, however, that only small readjustments will result from this cause.

Comparisons of various pressures should be made on the basis of a fixed total temperature rather than a fixed superheat. Such curves flatten out considerably around 1000 lb. Bleeder heating increases the pressures that are commercially economical. For a single stage of reheatimg the best reheat pressure is theoretically about one-third the initial, but practically about one-fifth.

With a 50,000-kw. unit, 1800 r.p.m., 350 lb., 725 deg. and 29-in. vacuum, a thermal efficiency of 29.54 per cent may be obtained without reheating. At 550 lb. (other conditions the same) this increases to 31.32 per cent and with reheating to 33.09 per cent.

Allowing for boiler losses this means that a kilowatt-hour can be obtained for 13,000 to 14,000 B.t.u., representing one pound of coal. The best present-day stations take about 1.3 lb. The Boston Edison is expecting to get 0.94 lb. with its 1200-lb. installation and may do even better. This will put the large steam plant in the same class as the Diesel engine as far as efficiency is concerned.—Eskil Berg in a lecture delivered before the Franklin Institute on Mar. 15, 1924, and reported in *Power*, April 1, p. 544.

Machining Massive Parts of the World's Largest Prime Movers

A Description of Methods Used for Machining the Large Cast-Steel Casings for the 70,000-Hp. Hydraulic Turbines Recently Installed at Niagara Falls

By EDWIN J. ARMSTRONG,[1] PHILADELPHIA, PA.

THE machining of unusually large parts, such as are used in the construction of high-powered hydraulic turbines, involves certain problems that are different from its usual run of machine-shop practice. The assembled units, which are composed of many sectional parts bolted together, become so large when ready for boring and turning that even the largest boring and turning mills now in use are too small to handle the huge castings by rotating them in the usual way, and other methods must be employed.

The huge sectional cast-steel casings for the two 70,000-hp. vertical-shaft-type hydraulic turbines recently built for the Niagara Falls Power Company in the shops of the I. P. Morris Department of The William Cramp & Sons Ship & Engine Building Company, are, as may be seen from Fig. 2, of an exceptionally heavy construction. They are of the spiral or volute form, having an inlet for the water, which is under 213 ft. head, 14 ft. in diameter and gradually reducing in size to about 4½ ft. diameter at the last guide vane. The width across the casing is 47 ft. 2 in. at the widest part and 38 ft. across the narrow part, and the greatest height at the inlet flange is 15 ft. 8 in. It is made up of eighteen separate sections, each piece of which is very close to the maximum size for rail shipment. The total weight when assembled ready for boring was 576,000 lb.

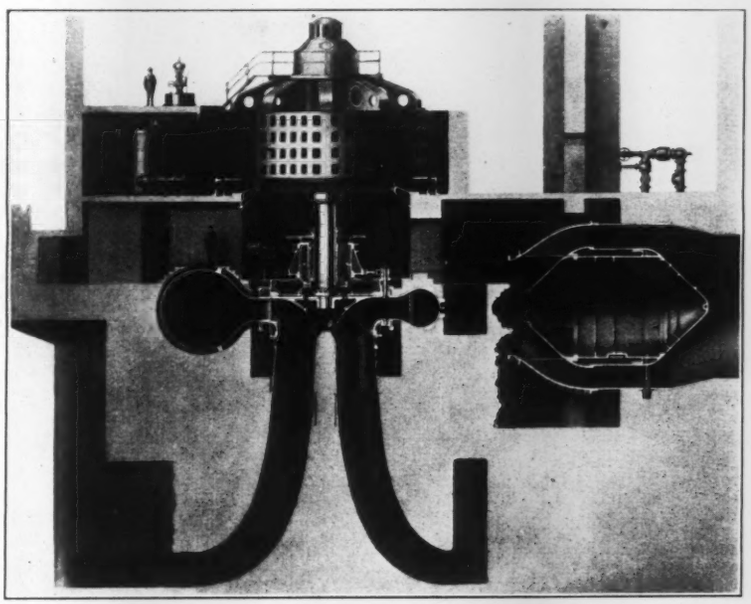


FIG. 1 SECTIONAL VIEW OF ASSEMBLED 70,000-HP. HYDRAULIC-TURBINE UNIT INSTALLED AT NIAGARA FALLS, WITH 14-FT. JOHNSON VALVE AT THE RIGHT

BORING AND FACING LARGE CAST-STEEL HYDRAULIC-TURBINE CASINGS

The casings were bored to receive the head covers to approximately 18 ft. 7½ in. and faced on the top and bottom internal flanges to 19 ft. 6 in. diameter; the height from top to bottom flanges was 6 ft. To swing the completely assembled casing would require a vertical boring mill capable of swinging a piece 50 ft. in diameter and having a height not less than 16 ft. from table to cross-rail and a boring bar that would reach down 11 ft. However, by removing some of the sections near the 14-ft. inlet, the joints of which are made in a longitudinal direction as well as radial in order to keep the several sections within the size required for rail shipment, it would be possible to reduce the maximum radius of the casing to 21 ft. With the casing thus reduced in size a boring mill would be required capable of swinging a piece 42 ft. in diameter and having a height under the cross-rail of 15 ft., a bar travel of 10 ft., and a table not less than 24 ft. in diameter, this latter requiring a circular track with ample bearing surface for it to rotate upon and capable of carrying a weight of 506,000 lb. on a diameter of about 20 ft. Granting that a boring mill of such size was available, another difficult problem would be to properly balance the casing on account of the unequal distribution of weight due to the inlet end being much larger and heavier than the small end of the volute.

The large size of the casings and the unequal distribution of weight makes the rotating of the work impractical. To stand the casing on its side and bore with a horizontal boring bar with a large spider to carry the boring tools would also be difficult. This would require a boring bar of very large diameter and supporting pedestals of sufficient height to carry the bar with its center 16 ft. above the floor line. Moreover, if the casing were bored when turned on its side there would be unavoidable distortion due to its great size and weight which would destroy the exact roundness of the bore when shifted to its normal position; and then, too, the moving of the casing from a horizontal position on the erecting floor to a vertical position would be a difficult job on account of its size and weight. Overhead traveling cranes could not handle the casing without dismantling some of the sections, and the work of reërecting in a vertical position would require considerable time as all the sections would have to be lowered to the shop floor, turned over 90 deg., and again hoisted up and assembled vertically. When the boring and facing operations were completed the operation of rehandling would be necessary.

The method finally adopted, Fig. 3, was to set up the casing centrally over a boring-mill table, supporting the casing in a horizontal position on stationary stands located on the shop floor around the boring-mill table, and revolve the boring and facing tools by means of suitable tool posts and slides secured to the revolving table.

The boring mill selected for the purpose was an extension vertical boring and turning mill having a swing of 20 ft. diameter with the housings in a forward position and one of 33 ft. when the housings are moved back; the height under the tool holders when the cross-rail is in its highest position is 15 ft. However, for the boring and facing operation on this job the cross-rail and housing are not required and they accordingly were moved to the back of the machine, which made the work of assembling the casing over the mill table much easier. The 50-hp. driving motor and gears for rotating the table are all located in a pit at the rear of the machine and below the top of the table. The extension bed and tracks carrying the housings are relatively low, thus allowing an unobstructed space for placing the work over the table and good supports for carrying and securing the casing. The boring-mill table is 18 ft. 8 in. in diameter and the finished bore of the casing is about the same size.

Surrounding the machine is a thick concrete floor which served to support the 183-ton partly dismantled casing on heavy cast-

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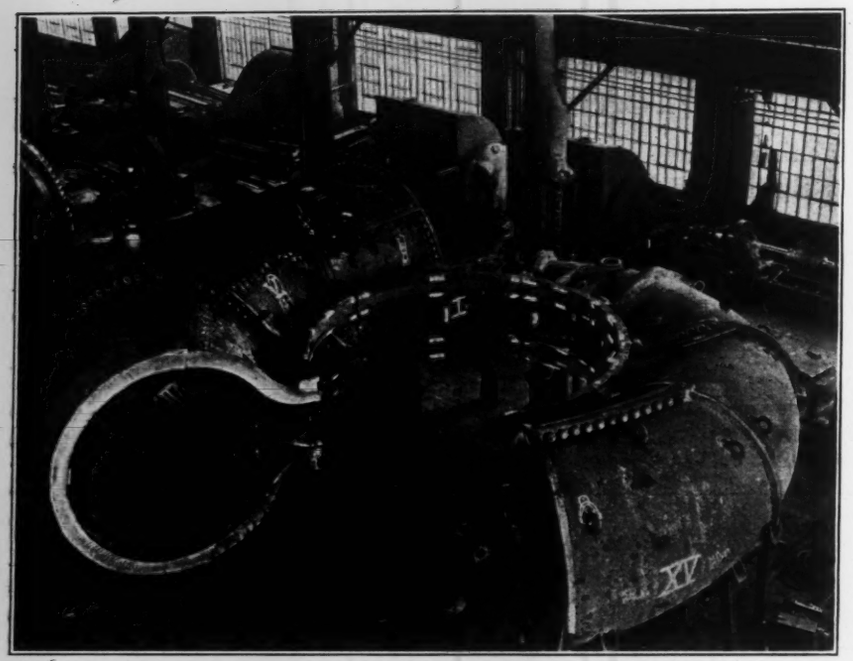

FIG. 2 THE VOLUTE TURBINE CASING PARTLY ASSEMBLED ON SHOP ERECTING FLOOR

iron pedestals spaced about 6 ft. apart. The pedestals are 5 ft. high and have two $2^1/_2$-in. set screws at the top which are used for leveling up the work. Large anchor bolts were used for clamping and steadying the casing, and threaded socket nuts were inserted in the concrete floor for securing the anchor bolts. At the back of the machine the casing was supported and clamped to the cast-iron extension bed or tracks for the movable housing, thus making a sturdy and rigid support for the work. To facilitate the setting a level line was scribed on each section of the assembled casing when fitted up and bolted together on the shop erecting floor, thus simplifying the setting on the boring mill.

Two cutting tools were used at a time, one working at the lower and one at the upper part of the casing. The cutting tools were held in sturdy tool holders attached to a vertical feeding saddle sliding on tool-post columns bolted securely to the revolving boring-mill table. The table of the boring mill, which is 18 ft. 8 in. in diameter, 19 in. deep at the edge, and has a center guide spindle 24 in. in diameter, together with the tool posts and slides, weighs 88,000 lb., thus making a substantial and rigid backing for the revolving tools.

The amount of metal to be removed varied from $^3/_4$ in. to $1^3/_4$ in. on a side; the average depth of cut when roughing out the bore was $^3/_8$ in. and the feed $^3/_{32}$ in.; the cutting speed was 30 ft. per min. All of the cutting was done dry without any lubricant, with high-speed-steel-tipped boring and turning tools. The total cutting time for the boring was 175 hr. per casing, and 47 hr. were consumed in setting up and dismantling the work, making the floor-to-floor time 222 hr.

The boring and facing of these giant casings were not the only unusual machining features. The surfacing of all the many flange joints required most careful study in order to meet delivery dates, as well as to keep down the cost, for each casing consisted of eighteen separate pieces, each piece being proportioned to keep within the maximum shipping size, which was approximately 10 ft. 6 in. in width and from 12 ft. to 14 ft. high, depending upon the width at top when placed on the cars for rail shipment.

An idea of the size of one complete turbine may be obtained from the fact that thirty-two cars were required to move the unit to Niagara Falls.

The casing has nine radial flange joints and fifteen longitudinal joints. The width of the flange-joint surface varies from $8^1/_2$ in. to $10^3/_4$ in., and the flange thickness from 3 in. to $4^1/_4$ in. Six hundred and seventy-nine bolts and nuts, varying from $2^1/_4$ in. to $3^1/_2$ in. in diameter, are required to bolt the eighteen sections together.

MACHINING THE FLANGE JOINTS OF THE TURBINE CASINGS

The machining of the flange joints presented another problem which was finally solved by constructing extra heavy face milling cutters capable of milling the steel castings with a depth of cut of from $^3/_8$ to $^{11}/_{16}$ in. Many turbines of smaller sizes have been constructed with casings of similar shapes, but the sectional parts have been of such a size that the flange joints could be machined by using 10-ft. and 12-ft. planing machines of the usual type. However, when the sections are large and heavy and constructed with curved and angular surfaces, it is impractical to clamp them on a planer table sufficiently rigid to take a heavy cut. Similar parts of turbines of a smaller size were surfaced by clamping the work upon large floor plate and using a vertical and horizontal planing machine with the cutting tool moving against the work. This method was successful as far as the work was concerned, but the progress was necessarily slow and it was decided to remove the planing and slotting head from this machine and convert it into a face milling machine.

A sturdy milling head capable of heavy-duty work was designed

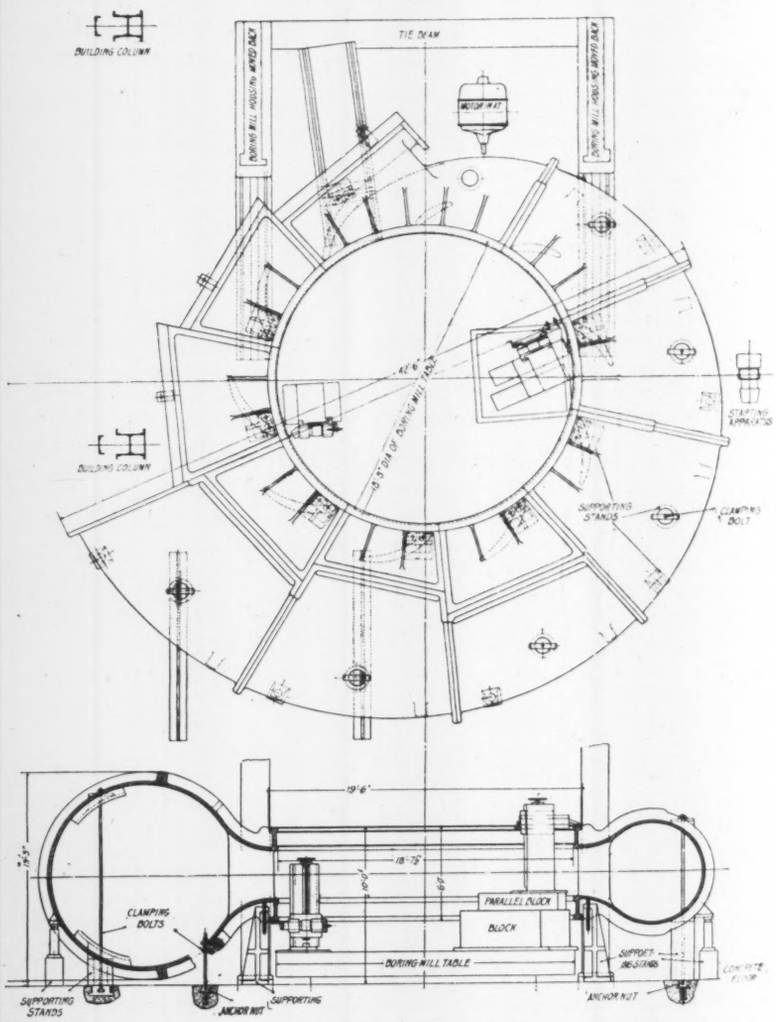

FIG. 3 METHOD EMPLOYED IN SUPPORTING AND CLAMPING 70,000-HP. TURBINE CASING OVER BORING-MILL TABLE

and constructed, the spindle being driven through heavy worm and spur gearing by a variable-speed motor. Two separate motors, one for vertical and one for horizontal travel, were used for feeding the milling cutter to the work. Many of the parts to be faced were circular and the milling feeds were arranged so that the face milling cutter could be fed around a circular path. This milling machine, Fig. 4, is capable of surfacing a piece 22 ft. long and 17 ft. high without resetting.

Considerable study and experimenting was necessary before the proper type of milling cutter was obtained. The cutters giving the best results were made with an extra heavy hardened-steel body with inserted high-speed-steel blades $^3/_4$ in. by $1^1/_4$ in. in section. The outside diameter of the cutter head is 16 in.; there are twenty-two cutting blades spaced equally around the circle, each blade fitting into a rectangular slot and secured with a clamp plate and screw. The cutting blades are set at an angle of 36 deg. with the axis of the head.

Cutter heads with blades set at an angle proved to be much more economical than those with blades set parallel with the axis. Due to the action of hard scale and burnt sand frequent grinding was necessary, and, as most of the cutting was done on the periphery, the outside diameter was reduced much faster than the front face of the blades where little grinding was required. By using cutter heads with adjustable blades set at an angle, the outside diameter could be restored by simply moving the blades forward. This type also served to maintain a deep space for chip clearance, which is quite necessary as the chips curl up similar to those of a boring mill if the proper rake and clearance angles are ground on the milling-cutter blades. The projection of the blades forward from the cutter-head housing should be from $^7/_8$ in. to $1^1/_8$ in. to enable the chips to curl up and free themselves.

The same type of milling cutters were used for roughing and finishing, except that the finishing-cutter blades were ground with slightly different land and clearance angles.

A special type of grinding machine, constructed especially for grinding face milling cutters, was installed as it is important to grind the cutters true to diameter and also to obtain the proper rake and clearances. One grinding would usually face on the first roughing cut from 35 to 50 sq. ft. of surface if the scale and sand encountered were not unusually hard. After the first cut, one grinding would face from 150 to 200 sq. ft. under normal conditions.

The amount of metal to be removed from the flange-joint surfaces varied from $^3/_4$ in. to $1^3/_4$ in., some of the sections having a flange area of 40 sq. ft. and a width and length of 15 ft. 8 in. The first roughing cut varied from $^3/_8$ in. to $^{11}/_{16}$ in. deep, depending upon the condition of the rough surface, it being necessary to cut well under the surface scale to protect the cutting edges of the tools. The feed for roughing was from $2^1/_2$ in. to 5 in. per min. with a cutting speed of 30 ft. per min. Care had to be exercised when making the first cut to slow down the feed and speed when cutting into unusually hard scale or sand. After the first cut was removed the feed could be maintained at a uniform rate of speed. Finishing cuts were $^1/_{64}$ in. deep and feeds from 10 in. to 12 in. per min.

No lubricant was used on the milling cutters, all of the cutting being on dry surfaces, with the exception that dead oil was applied to the original rough surfaces by a brush merely to loosen and remove any pieces of loose scale or sand.

The milling cutters are capable of removing metal with a cut $^{11}/_{16}$ in. deep and feeds from $2^1/_2$ in. to 3 in. per min., but a cut $^7/_{16}$ in. deep with a 5-in. feed gave better results and avoided vibration in the milling machine and the work.

Machining the Casing of a Huge Johnson Hydraulic Valve

Another large element of the gigantic turbine that required special machining methods was the cast-steel casing for the Johnson hydraulic valve which is shown at the right in Fig. 1. Three of these valves were built to be connected to the three 70,000-hp. turbines for the Niagara Falls plant.

The valve is installed between the outlet end of the 21-ft.-diameter penstock and the inlet to the main turbine casing. Its function is to quickly shut off the flow of water to the turbine in case of emergencies and to provide ready means of unwatering the turbine at any time for inspection and maintenance, without unwatering the entire penstock. It is a plunger-type valve with the axis horizontal and operates automatically by hydraulic control.

The casing, Figs. 5 and 6, is a large bell-shaped shell; the inlet diameter is 24 ft. 4 in., the outlet diameter 14 ft., and the overall length 12 ft. $10^1/_4$ in. In order to keep within shipping sizes the casing is made in four sections with the joints radial. The casing weighs 240,000 lb. The main bore for the plunger fit is 15 ft. 2 in., and is continuous for a length of 7 ft. $6^3/_4$ in.

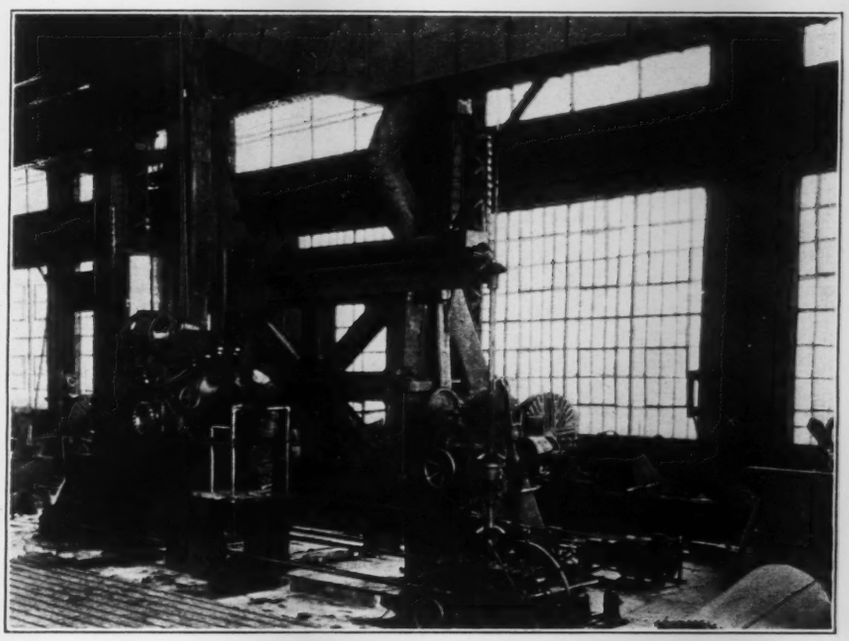

Fig. 4 Face Milling Machine Capable of Milling a Surface 22 Ft. Long and 17 Ft. High at One Setting

The operation of facing the flanges previous to bolting together for boring was the same as with the turbine-casing sections.

On account of its shape and the large bore it is not practical to support the casing on the table of a regular-type boring mill. It would be possible to place the 14-ft. end of the casing on a mill swinging $26^1/_2$ ft. or more, but it would require a boring bar with a travel of 12 ft. $10^1/_4$ in. to reach the bottom of the casting. To bore down to a depth of 6 ft. 6 in. from the top and then turn the casting over and bore about the same distance from the other end would not be a good proposition, as the bore for the plunger fit, which is 15 ft. 2 in. in diameter and 7 ft. $6^3/_4$ in. long should be a continuous bore without resetting the casting.

The method used for boring and facing these castings, there being three to machine, was similar to that employed for the main turbine casings, that is, to support the casing in a stationary position, centrally over a boring-mill table, and to revolve the cutting tools. A 16–25-ft. extension vertical boring and turning mill was used for this job. Referring to Fig. 6, the supporting blocks for holding the casing were placed on the heavy concrete floor in front of the boring mill and on the extension bed or housing tracks in the rear of the machine, in about the same manner as the method described above for the large volute turbine casing.

In order to take care of the long continuous bore for the sliding plunger it was necessary to remove the boring-mill housings from the bed of the machine and bolt them securely to the revolving table. To rigidly support the mill housings, which are 17 ft. 6 in. high and set up parallel about 10 ft. apart on the table, a heavy structural-steel diagonal brace made of 4 x 4 x $^1/_2$-in. and 3 x 5 x $^1/_2$-in. angles was securely attached to the housings. On the face

of each housing, mounted on suitable cast-iron backets, was bolted a long tool slide with a saddle and tool holder similar to a planer cross-rail. The tool slides were set at an angle of about 45 deg. to the face of the housing in order to bring the cutting tools radial. In addition to the two tools on the housing, two other tools were used for boring, making four tools working at a time. The lower boring tools were mounted on tool posts 6 ft. high, bolted to the table and revolving with it.

The amount of metal to be removed varied from $^3/_4$ in. to $1^3/_4$ in.

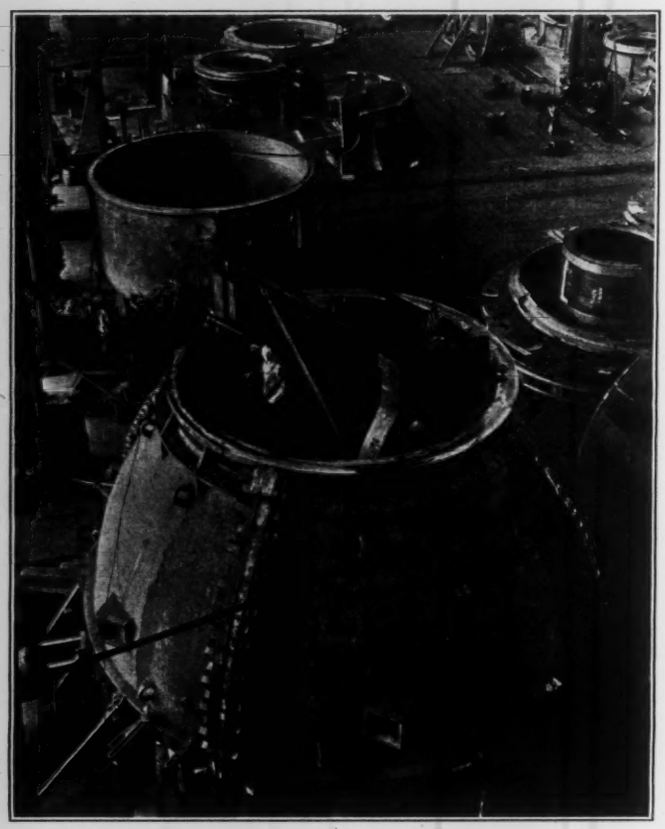

FIG. 5 JOHNSON VALVE CASING ON 16–25-FT. EXTENSION BORING MILL. NOTE THAT THE BORING-MILL HOUSINGS ARE BRACED TOGETHER AND REVOLVE WITH THE TABLE

on a side; the average depth of roughing cut was $^3/_8$ in. and the feed $^3/_{32}$ in.; the cutting speed was 30 ft. per min.—all about the same as in the case of the large volute casings.

The total cutting time for boring and facing the cast-steel casing was 262 hr., to which must be added 39 hr. for finishing the brass bands and liners which were attached to the steel casting by round-head tap screws while the casing remained in place on the mill. The time required for setting up the casing on the support blocks was 47 hr. The floor-to-floor time, including the removal of the cross-rail, feed mechanism, and housings of the boring mill and reërecting them after the job was removed, also drilling and tapping the brass-liner bolt holes, was 539 hr. per casing.

Another interesting machining feature is the drilling, boring, spot facing, and tapping of the large bolt holes required for bolting the cast-steel sections together at the flange joints. The bolts vary in diameter from $2^1/_4$ in. to $3^3/_4$ in. All the holes are drilled and bored from the solid flanges which are from 3 in. to $4^1/_4$ in. thick. Machines of the floor-borer type were used, having horizontal spindles, with suitable speeds for drilling, boring, and tapping. The feed of the spindle is in a horizontal direction, the vertical traverse being obtained by a sliding saddle carrying the spindle, located on the side of a traveling column or post, mounted on a bedplate, and arranged for horizontal traverse at right angles to the spindle. The work is clamped to a floor plate in front of the machine with the joint surface vertical, large knee brackets 10, 12, and 14 ft. high being placed in back of the work to resist the thrust of the drill. This method of drilling is employed for large work which is beyond the capacity of the largest radial drill presses.

There are other large heavy parts used in the construction of these high-powered hydraulic turbines, such as the cast-steel runners weighing 105,000 lb., the head covers weighing 102,000 lb., and the cylinders and plungers for the Johnson valves weighing 92,000 lb. and 75,000 lb., respectively. However, all of these parts, although large and heavy, can be machined on the usual type of extra heavy boring mills having large-diameter tables and extra high vertical distances from the table to under side of tool holders, and so present no unusual problems such as the one encountered in the machining of the parts discussed.

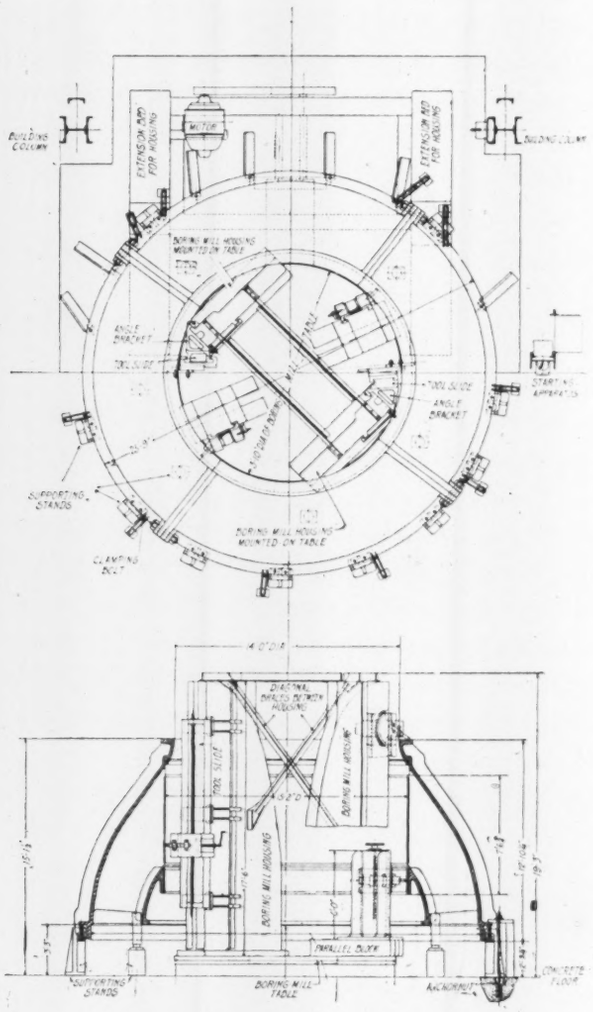

FIG. 6 JOHNSON VALVE CASING IN POSITION OVER BORING-MILL TABLE FOR BORING AND TURNING

Discussion

W. M. WHITE.[1] Because of the writer's close acquaintance with the type of castings described in Mr. Armstrong's paper, he can readily appreciate the many difficulties encountered in their machining. The solution which the Cramp Company engineers have arrived at for the boring of the Niagara Falls cast-steel spiral casing is almost exactly the method used by the Allis-Chalmers Manufacturing Company in 1921 for boring the spiral casing for the 40,000-hp. hydraulic turbines for the Pacific Gas and Electric Company.

This casing would have required a mill capable of clearing 40 ft. in diameter. It was to be bored about 11 ft. 6 in. By removing the heads of the machine and erecting the casing around the table of the boring mill, we were successful in producing a very satis-

[1] Mgr. & Ch. Engr., Hyd. Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

factory job. Even had a mill been available to turn a piece of this diameter and weight, it is believed that the method used, that is, with a revolving tool and the casing erected on the floor surrounding the mill, was much the better procedure, since it eliminated the vibration and jarring so likely to occur when large masses are placed on a revolving table and heavy cuts are taken.

As a decided contrast to the 70,000-hp. unit which the I. P. Morris Department of the Wm. Cramp & Sons Ship and Engine Building Company are building for the Niagara Falls Power Company, we believe that the unit which the Allis-Chalmers Manufacturing Company, of Milwaukee, are building for installation in the same power house, also rated 70,000 hp. offers much the simpler solution as regards machine-shop and foundry work, without in the least sacrificing in any measure reliability or strength. In fact, we, and many others, believe that the plate-steel spiral casing riveted to a cast-steel speed ring is much the more reliable solution.

Fig. 7 shows the cast-steel speed ring when the plate-steel spiral casing is being erected on it in the shop. The speed ring, which is made of five sections, is bored to an inside diameter of 20 ft. and turned to an outside diameter of about 26 ft. This can be quite readily handled on the ordinary type of boring mill. The sections of the plate-steel spiral casing do not require any of the complicated machining operations which are required to produce a perfect fit in the cast-steel casing. The plates are laid out and the rivet holes punched in the flat. They are then rolled to diameter and the edges crimped for fitting the adjoining plates. The sections are then fitted up to the speed ring and all rivet holes reamed together. The saving in the amount of work required can be appreciated somewhat by the difference in the actual weight of these two machines, both of which were rated 70,000 hp. The cast-steel casing of the I. P. Morris turbine weighed 576,000 lb., whereas the combined weight of the cast-steel speed ring, the plate-steel spiral casing, and the inlet pipe of the 70,000-hp. Allis-Chalmers turbine was only 400,000 lb.

At times the question of the strength of the plate-steel spiral casing so constructed has been questioned by some people. Actual

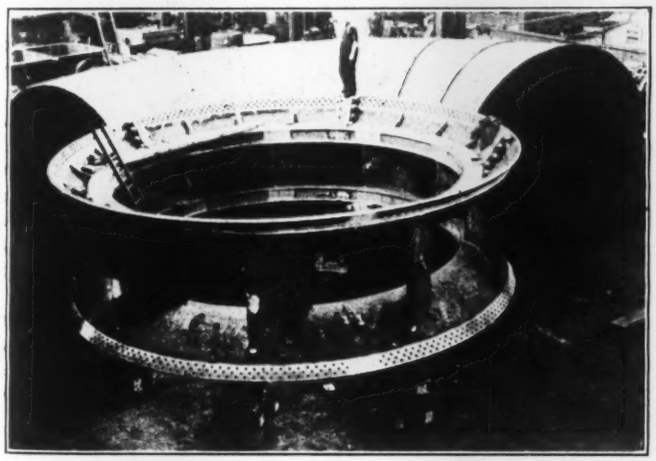

FIG. 7 PLATE-STEEL SPIRAL CASING AND CAST-STEEL SPEED RING FOR 70,000-HP. TURBINE NOW BEING BUILT FOR THE NIAGARA FALLS POWER COMPANY

(Inlet diam., 15 ft.; plate thickness, 7/8 in. to 1 1/4 in. Speed ring: Outside diam., 26 ft.; bore, 20 ft.; weight, 143,750 lb.)

tests have shown that plate-steel spiral casings constructed with flanged plate of special quality properly rolled and riveted, are far superior to the steel castings, the uniformity of which is always questionable. We know that in forging a shaft we materially increase its strength and ductility. The same is true of the plate. In rolling plates from the ingot the quality of the steel is greatly improved. Naturally, it is impossible to so improve the quality of the steel in a cast-steel casing, and we frequently find that some sections of intricate steel castings like these casings must be rejected because of too great a number of blowholes, porous section, or other imperfections in the casting. The fact that we no longer use penstocks constructed of cast steel should be ample reason for discarding their use wherever possible for the spiral casing as well.

In boring the housing for the 23-ft.-6-in.-diameter butterfly valves used for controlling the water at the headworks of the penstocks feeding the three 70,000-hp. units of the Niagara Falls Power Company and which are the largest in the world, we encountered the same problem as in boring the inside of the large cast-steel spiral casing. Fig. 8 shows the housing, which would have required a boring mill capable of turning a diameter of 31 ft.,

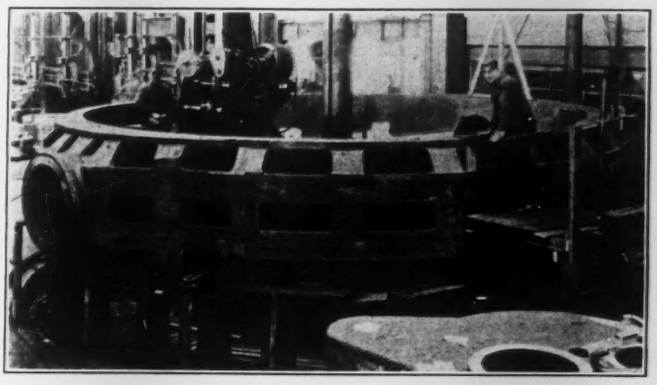

FIG. 8 MACHINING WICKET SEAT IN 23 1/2-FT.-DIAMETER BUTTERFLY VALVE

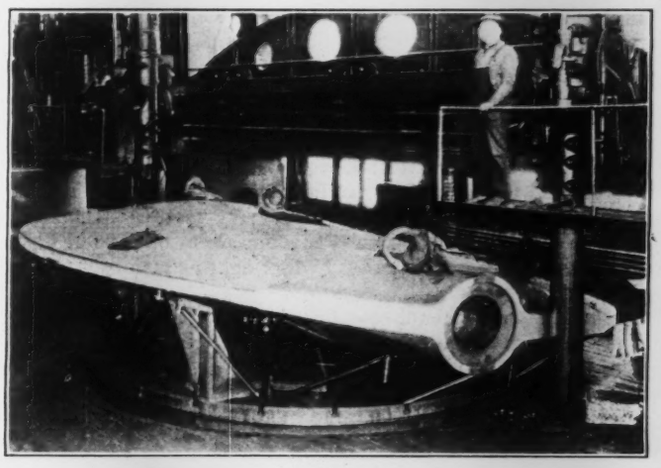

FIG. 9 MACHINING WICKET FOR 23 1/2-FT.-DIAMETER BUTTERFLY VALVE

mounted around the outside of the boring-mill table, very similar to the operation of the boring out of the cast-steel spiral casing. Fig. 9 shows the 23-ft.-6-in.-diameter wicket supported on the revolving table of the boring mill for turning it at the proper angle. The many braces and special castings supporting the wicket are clearly shown in this view.

Water Power in Canada

DURING 1923, 253,655 hp. of turbines and water wheels were installed in Canada, bringing the total installed capacity to 3,227,414 hp., an increase of over a quarter of a million hp., while the growing demand for power is demonstrated by the numerous large developments being rapidly pushed to completion. These new developments are not confined to any particular section of the country but extend from coast to coast and are designed to serve practically every community where a demand for power exists. The Dominion Water Power Branch state that the present recorded water-power resources of the Dominion will permit a turbine installation of 41,700,000 hp.

The total installation may be classified as follows: (*a*) 2,411,701 hp. in central stations for general distribution for all purposes, of which 1,644,071 are in privately owned stations and 767,630 in publicly owned stations; (*b*) 497,620 hp. in 121 pulp and paper mills; (*c*) 318,093 hp. in industries other than central stations and pulp and paper mills. The total installation for the Dominion is 353 hp. per thousand population.

Some Production Problems in the War Department's Preparedness Program

By CAPT. H. W. CHURCHILL,[1] NEW YORK, N. Y.

IN AN article on Ordnance Industrial Mobilization published in the November, 1923, issue of MECHANICAL ENGINEERING, General C. C. Williams, Chief of Ordnance, has set forth the general plans under which the War Department is operating to further industrial preparedness. For the first time in our history we have a definite military policy, in sharp contrast to the policy of drift which has controlled our destiny for nearly a century and a half and cost us hundreds of thousands of lives and many millions of dollars. The National Defense Act of June 4, 1920, charges the Assistant Secretary of War with the responsibility of planning for the industrial mobilization of the United States which duty is delegated directly to the Assistant Secretary and through him to the chiefs of the several supply branches of the Army. The Secretary of War has adopted the district-office plan as the basis for the procurement, inspection, and shipment of material required in the event of another major emergency.

An enormous saving in dollars can be made each year during peace time by any plan that will insure an early supply of munitions and equipment in time of war. Until the industries of this country can send forth an even flow of sufficient matériel the armies must be adequately supplied from a reserve stock that must be maintained year after year, at a heavy expense for storage, upkeep, deterioration, and replacement. If, as has been estimated, it will require twelve months for the industries to get into production of munitions, a vastly greater reserve stock of all matériel must be kept on hand than would be required were production to reach its maximum in six months. Therefore every month cut from the estimated time of getting into production saves millions of dollars to the taxpayers—and countless lives of fighting men by the shortening of the war.

Definite monthly requirements on each of the major items of munitions, equipment, and supplies have been figured by the various supply branches of the Army, these requirements being based on carefully accumulated data compiled during the last war and applied to the program of mobilization as adopted by the General Staff in compliance with the National Defense Act. These total monthly requirements have been divided and allocated to the various industrial districts according to the available manufacturing facilities, sources of raw materials, main-line transportation, and field-service storage and distributing centers.

Each district office of the several branches of the service is presided over by an officer of the Regular Army, or by a prominent local business man, assisted by an officer of the Army acting as executive assistant. It is the duty of these officers to make such a complete survey of the industrial resources of the districts as will insure the placing of tentative wartime contracts with those manufacturers best fitted to produce the matériel most expeditiously and economically.

Cooperation of Engineering, Industrial and Commercial Bodies with the War Department

The problems of the War Department District Offices are vast, and it is only through enthusiastic coöperation of the industrialists of the country that they can be solved satisfactorily. The contacts made thus far have been very gratifying to those of us who have been assigned to the work of carrying the program to completion. The engineering societies have been especially conspicuous in their offers of assistance and already have responded to the calls for aid that have come from the War Department. The offers from the societies have come not only from the societies as a whole, but from various committees and officials who have offered their services. The Ordnance Division Executive Committee has been consulted about engineering problems in the design and manufacture of Ordnance matériel, and great value has been derived from their work. The American Engineering Standards Committee is working closely with the General Staff in the establishing of standards in specifications governing much material required by the several branches of the service.

Manufacturing associations, chambers of commerce, local engineering societies, and other similar organizations throughout the country have expressed their desire to assist in every way possible this movement for industrial preparedness, and in many instances advantage has been taken of their offers. Trade organizations, and in some cases individual manufacturers, have put at the disposal of the War Planning Sections such facilities as they have for supplying information and advice.

Many manufacturers of material for the War Department have felt that the specifications under which they had to work were altogether too severe. In some cases this may have been true; in others it is found that the terrific strains under which war material must function requires better workmanship and stronger parts than would be deemed necessary for commercial consumption of somewhat similar products. The failure of a few pieces of artillery may lose a battle; the jamming of a cartridge may mean the death of another United States soldier. However, the engineering departments of the various branches of the Army are adopting standard specifications wherever possible in place of the specifications that formerly were insisted upon.

An enumeration of the problems most urgent at this time will illustrate the difficulties which the War Department faces.

The Reserve-Officer Personnel Problem

First, the problem of reserve-officer personnel required for duty in each district furnishes a wonderful opportunity for the engineering societies to lend their assistance in securing that type of man best qualified to understand the manufacturer's viewpoints. These officers are the men who will be direct in charge of the procurement, inspection, shipment, and payment for all War Department matériel produced in the several districts. The organization needed to handle a program running into hundreds of millions of dollars a year must function intelligently to insure against disastrous delays in production and unnecessary losses to both the contractors and Government.

The District Office organization requires mechanical, chemical, and construction engineers, financial and accounting experts, statisticians, transportation specialists, administrative executives, production men, men capable of taking charge of inspection and tests. Thousands of such officers are required.

A typical District Office organization may be illustrated by the Ordnance Department layout. Each of the fo irteen districts is patterned as nearly as possible after the Office of the Chief of Ordnance in Washington, so that the subdivisions in the districts can work more closely with the corresponding divisions in the head office. Directly representing the Chief of Ordnance is a District Chief, a man chosen for his knowledge of the industrial situation in his district and for his proven ability as an organizer and executive. His district organization is broken up into divisions, each handling its own work independently. In the executive office are such divisions as, Business, Advisory, Technical Advisory, Finance, Administration, Contract, Transportation and Increased Plant Facilities. On an equal footing with these, and responsible directly to the District Chief, are the five manufacturing divisions: Artillery, Ammunition, Aircraft, Armament, Tank, Tractor and Trailer, and Small Arms. The work of these divisions is carried on by sections each handling its particular type of matériel.

Practically every bit of the responsibility for the production and shipment of war-time munitions will rest upon the shoulders of the reserve officers who will be called to active service. These men

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must be trained in time of peace so that they can start functioning immediately upon a declaration of war. To train every reserve officer so that he might successfully fill any assignment to which he might be ordered would be absolutely incompatible with economy and with the time these men could spare from their commercial activities—and equally unnecessary. It is intended that each reserve officer shall be trained for a specific duty; and since a man's special education and experience are the qualifying factors in assigning him for that specific duty, the time he must spend in preparing himself will be reduced to a minimum. This preparation will be accomplished through occasional lectures and demonstrations at times convenient to the reserve officers and by pamphlets and papers that will be distributed to them for their duty.

Commissions are granted for a period of five years, at the expiration of which time an officer can withdraw from the reserves if he so desires. These next five years are the critical ones in perfecting the plans for war preparedness, however, and the services of capable men whose experiences would be valuable to the War Department are very much needed. A patriotic duty can be accomplished by aiding in the building of the foundations now, at the same time preparing younger and less experienced men to carry on the work of the future.

THE PROBLEM OF SECURING FACILITIES FOR MANUFACTURING WAR MATERIEL

The problem of securing facilities for the manufacturing of war matériel is the greatest one. Advantage must be taken of such machinery and organizations as are already in existence if we are to get into maximum production in the minimum time. Therefore, to find this mechanical equipment presided over by competent executive and operating personnel, is the first step to be taken by the District Chiefs.

The Ordnance Department for example, is charged with the supply of some 1200 articles of issue. They comprise some 250,000 components. When it is realized that millions of some of these major items are needed every month in time of war the necessity for careful planning is evident. It is not sufficient that the War Department shall have located the proper facilities for the manufacturing of these items, nor even that it shall have arranged for any additinal machinery needed by individual manufacturers. Unless each manufacturer develops his own war plans for getting into production at the earliest possible moment, has worked up his requirements for tools, gages, equipment, raw material, labor, and transportation, there will be months of unnecessary delay costing our country the lives of many of her defenders and incalculable financial loss and perhaps defeat before a better-prepared enemy.

So the burden of preparedness rests not alone upon the War Department but also upon the manufacturers of the country. With their coöperation such a preparedness program can be developed as to make it very inadvisable for any enemy to draw the United States into a war; or, if war is forced upon us, a program that will lead to an earlier and more complete victory.

For economic and military reasons it is necessary to obtain all components within as small a radius as possible, that the supply of completed units may flow steadily and with the minimum transportation toward the battle zones. For the 75-mm. high-explosive shell there must be procured the steel shell forgings—which must then be machined, brass cartridge cases, copper rotating bands, fuzes, adapters, boosters, fuze sockets and holders, and several minor parts. The ideal condition from the point of view of the War Department would be to secure the complete round, loaded, assembled and boxed, from a single prime contractor. But the commercial equipments of industrial plants do not permit of any one manufacturer turning out all of this varied material without calling upon other sources. Some contractors believe it would be an advantage to all were they allowed to take a contract for the entire round, sub-contracting for the material they could not make themselves; others prefer to take contracts for such of the components as can be produced in their own plants, the Government supplying the remainder of the parts ready for assembling. Under any circumstances new loading facilities will have to be developed. This problem is one that is causing no little concern in the District Offices of the Ordnance Department.

PROBLEMS TYPICAL OF THOSE CONFRONTING PLANT PRODUCTION ENGINEERS

As an example of the problem as it reaches the production engineers in the plants of the contractors, let us take this same 75-mm. H. E. round, or at least one or two of the components. The tentative contract having been agreed upon by the executives of a plant, the engineers are faced with the problems of developing the method of manufacture. By carefully working out these problems in advance, production can be attained in a much shorter time than by having to start when the war is declared; and it is here that the engineers can be of such enormous value to their country.

When the tentative contract has been agreed upon there will be delivered to the manufacturer a complete set of Van Dyke prints and specifications covering the matériel to be produced, together with such gage and tool drawings, and outlines of methods of manufacture as are available. In storage in some of the arsenals are sets of tools and fixtures on certain Ordnance matériel that were taken over in settlement contracts after the last war. Only the best of these were preserved, and they will be available for distribution to those manufacturing whose machine-tool equipment will permit of their use.

Assuming that shell forgings will be furnished, what method of machining will be adopted to turn out the finished shell body? Route sheets must be developed, consistent with the facilities at hand; types and sizes of new machinery and heat-treating equipment must be determined and a source from which these may be obtained must be ascertained; perhaps single-purpose machines must be designed and plans established for their procurement; tools and fixtures must be drafted and studied; gages must be provided for, both for the various operations and for the final inspection. It is no small task; yet at this very point disastrous delays may ensue. The problems of sufficient and capable labor must be threshed out. Hundreds of thousands of mechanics and machine-tool operators will go into the Army and Navy and substitutes must be found. The last war proved that operations could be so laid out that women could turn out very successfully a large percentage of our munitions of war. I have seen a plant where none but women were used in the rough turning of our 155-mm. shells, even the assistants to the foremen in charge being women; and I have seen fuze plants where only women operators were to be found throughout the entire plant.

In the case of the fuze the matter of providing facilities is simple. Any quantity of commercial machines always are available. But here, with so many small components to be made, the tooling, routing, gaging, and assembling in large quantities is a big problem.

The drawing of brass cartridge cases is unlike most commercial press-work. Starting with a flat, round disk there must be produced a brass case 14 in. long for the H.E. or 27 in. long for the anti-aircraft shells. These cases must be drawn with walls not over 0.06 in. thick at the mouth, tapering up to 0.08 in. at the base free from pipes and seams, with a base a little less than $^3/_8$ in. thick and free from annular rings. The calculating of the types and sizes of presses best adapted for this work, the design of the dies that will perform best under quantity production, the forming tools for machining the base, the annealing and pickling processes—all of these require careful study and design if our armies are to be supplied with the needed ammunition with a minimum of delay.

Within a very few years the supply of war reserves will have been entirely dissipated and new stocks must be obtained from year to year. It has been proposed that peace-time orders be placed with manufacturers, these orders including not only the required munitions but also the tools and gages required to produce on a quantity basis. These tools would then be placed in storage by the contractors in a stand-by condition, ready for instant use in case of war. In the course of a few years tools and fixtures for all the most important items would come into existence and would form a very substantial basis in the preparedness program. This plant is contingent upon Congress making the necessary appropriations. The direct saving in the reduction in war reserve carried in peace time would repay this original investment; and the saving in the event of war, through the speedier starting of production, would be enormous.

FEATURES OF THE TYPE OF CONTRACT NOW BEING DEVELOPED

During the last war there were numerous types and forms of contracts. Some of these worked severe hardships upon the manufacturers; others were costly and unsatisfactory to the Government. To eliminate, as far as possible, the unsatisfactory results of these contracts, a board of officers, headed by Brigadier General Ruggles, Assistant Chief of Ordnance, has been working for many months, drawing up a type of contract fair to all. Sample contracts have been developed and copies sent to various manufacturers for comment and suggestions. Revised samples have been submitted and further changes suggested. Eventually a contract will be whipped into shape that will embody the best thoughts of the commercial and military minds.

One stipulation of the contracts so far developed has been that a sliding price should be provided, one of the factors determining the price being that of increased wages. This question has been the basis of a great deal of discussion and some of our most able industrial executives have pointed out that such a provision would but open the door to unlimited demands by labor for constantly increased pay. These executives, many of them now employing thousands of workers, feel that the manufacturer is the only buffer that can securely be wedged between labor demands and the public. They advance the belief that the manufacturer will be able to absorb possible added labor costs by the development of labor-saving tools and operations and by increased production if compelled to do so. This is another very important problem upon which discussion is greatly desired.

The exemption of certain individuals and groups of skilled mechanics from military service is one that demands careful consideration and the development of plans that will retain for war industries the essential workers without doing injustice to the fighters or hampering the armed forces of the country. Beginning with the executives and engineers and passing on down through foremen and toolmakers, the skilled mechanics and artizans, some definite, prearranged method of assuring necessary labor for the production of war matériel and civilian requirements must be determined. The women of the country and the physically unfit and exempted men must carry on the industries without interruption, as far as possible.

RAW MATERIALS—GAGES—MACHINE TOOLS

Another great study that confronts the War Department is the supply of raw materials. A group of experts is working on the problem of assuring the supply of strategic raw materials that must be imported, endeavoring to find satisfactory substitutes and formulating plants to keep the sea lanes open. Where raw materials are obtainable in this country it is believed advisable for each contractor to obtain his own requirements in the opening months of war, as far as possible. At the same time boards similar to the War Industries Board will be organized and will prepare themselves to take hold of problems of raw materials as rapidly as they become important, eventually allocating where most needed all materials in which a shortage seems likely.

Even now the art of and facilities for, the production of certain materials such as acid steel, some explosives, and other components from which munitions and supplies have been made, are passing out of existence. It is necessary that substitutes be found or that some method of retaining a nucleus for expansion in time of an emergency shall be devised.

The gage question is one that has received much attention in the Office of the Chief of Ordnance, and, to a lesser extent because of the lesser requirements, in other supply branches of the War Department. Lack of appropriations of sufficient size has prevented carrying out to completion the plan to manufacture and place in storage those gages that are absolutely necessary to early production. The policy adopted by the Chief of Ordnance calls for master gages and one set of final-inspection gages for every contract where gages are required. Many sets of serviceable gages were accumulated after the signing of the armistice in 1918 and these have been carefully checked, tabulated, greased, and stored, and form the basis upon which our gage supply is being built. The Ordnance Department gage designers are combining their knowledge and experience with that of many of the most successful manufacturers so that the new designs may be most economically manufactured and still satisfactorily perform their functions.

Some progressive manufacturers to whom tentative allocations have been made have expressed their determinations to devise and design single-purpose, special machinery to facilitate production and lessen costs of operation. This work, it is contemplated, will be performed by their engineers from time to time when the plants suffer those lulls that occur every so often. Upon the successful development of just such plans and others that embody preparedness within the plants themselves depends the success of our next war, its loss of life, and its cost. Even in peace times, can the War Department be assured that industry will get into the required quantity production earlier than contemplated, millions of dollars may be saved by cutting down the war reserves of munitions.

The matter of securing the machine tools necessary to complete the batteries needed to turn out munitions must be analyzed. It is the hope of the War Department that each manufacturer of munitions and supplies will so study his needs that he will be able to furnish the local District Chief of the War Plans Sections with specifications of his requirements. The plans whereby this machinery can be supplied will be tackled and solved. Probably this is one of the most urgent problems that must be met. I have seen the lack of one hydraulic nosing-in press hold up an otherwise completely equipped plant for weeks.

The extent to which this country will be prepared to meet any emergency that might arise depends to a great extent upon the industries of the country and upon the engineers within those industries. If the local branches of The American Society of Mechanical Engineers and of other engineering bodies would devote meetings to the problems of the districts in which they are located, and would continue into their plants the industrial-preparedness plans that are being perfected up to their front doors by the War Department, this country of ours would be carrying such a strong insurance policy against war that no enemy nor logical combination of enemies would dare to attack us nor drag us into any conflict upon which they might contemplate entering.

To quote from General Williams' article in MECHANICAL ENGINEERING, "The outlay in time of peace to secure this condition of preparedness is not excessive. The coöperation of the potential producers is the most important consideration. A relatively small amount of coöperation from the many potential producers in this country is rapidly placing the United States in a state of industrial preparedness immeasurably better than ever before in the history of the country."

Discussion

CAPTAIN Churchill's paper was presented at the session of the Ordnance Division on December 5, 1923, at the Annual Meeting of The American Society of Mechanical Engineers.

Fred J. Miller, Past-President of the A.S.M.E. and Chairman of the Ordnance Division, presided, and in opening the session pointed out that there is a strong sentiment against aggressive warfare but that the preparation needed to commence the manufacture of munitions when war threatens is vital.

Following the presentation of Captain Churchill's paper, Brig. Gen. C. L'H. Ruggles[1] pointed out that the tremendous man power of the United States would be useless in time of defensive emergency unless it had adequate and prompt supply of weapons and munition. In the discussion that followed representatives of a large number of manufacturing concerns pledged their support of the National Defense Act and promised hearty coöperation in the work of the War Department in industrial mobilization.

Otto Best[2] pointed out the necessity of continual peace-time manufacture of ordnance material in small quantities in order to have the personnel thoroughly understand the needs of the War Department. Alten S. Miller[3] expressed his feeling that a considerable part of the preliminary work should be done by the Ordnance Department in collecting existing data on the requirements for manufacture covering ground space, floor space, equip-

[1] Assistant Chief of Ordnance, U. S. A., Washington, D. C. Mem. A.S.M.E.

[2] Factory Supt., Nathan Mfg. Co., New York.

[3] Bartlett-Hayward Co., Baltimore, Md. Mem. A.S.M.E.

ment, jigs, fixtures, tools, and gages. Such information is in existence but as plants have now been converted to other work and the individuals who were interested in the manufacture of ordnance materials are being scattered, it will be more and more difficult to assemble the information as time goes on, and it is supremely important to get the information now. There will be no plants capable of making munitions in any quantities when the next war starts. The Ordnance Department should be in a position to hand a contractor complete drawings and specifications of the ammunition required, as well as information that would permit the contractor to immediately secure the necessary land, the necessary floor space and complete equipment, without any delay to study methods, routing, etc. If this is done there will be a saving of many months in the delivery of finished guns and ammunition, and the principle efforts at the present time should be placed on securing and tabulating the available data. Luther D. Burlingame[1] pointed out that the machine-tool builders must confine their war efforts solely to that of increasing production of their regular product. B. H. Blood[2] concurred with Mr. Burlingame in this. C. K. Decherd[3] suggested that the War Department be in a position to show manufacturers what they can make in time of war that is parallel to their normal line of manufacture. George B. Warner[4] pointed out the great delay arising from the necessity for such tools to produce ordnance material in quantity. W. S. McIntosh[5] emphasized the importance of keeping gages and tools up to date. J. G. Worker[6] suggested that manufacturers present a list of the men in their organizations to the Government as the basis for selecting the men to do inspection and production work in the district office of the Ordnance Department. He also emphasized the need of a proper form of contract for Government work in time of emergency, and the importance of coördinating the various procurement agencies of the Government. R. K. Blanchard[7] related his experience with drawings bearing incorrect limits when the manufacture of ordnance was taken up for the first time during the last war. He also pointed out the value of coöperation between the manufacturers of various items of ordnance material. F. E. Swope[8] related difficulties of developing the manufacture of such ordnance material such as tracer bullets, aircraft ammunition, etc., which should have small units in constant operation in order to properly develop the art. J. R. Byrne[9] suggested the importance of correlating the experience of all manufacturers who worked on the same article to determine the best type of machinery to procure for any problem of manufacture. Mr. Henning[10] pointed out that it was the function of the Army Ordnance Association to keep ordnance manufacturers informed as to developments in ordnance manufacture. He urged the importance of constant peace-time contact between the manufacturing organizations on the one hand, and the Ordnance Department of the Army and the Bureau of Ordnance of the Navy on the other, to facilitate the training of personnel and the expansion of production in time of emergency.

The Ordnance Department gave careful consideration to the comments of the various discussers and wrote in substance that as to Mr. Best's suggestions there was no question but that a plant could get into quantity production of any article much more easily and quickly in time of war if it had sufficient orders in peace time to keep up the production of a small quantity of the article continuously. This would insure that manufacturing methods were worked out in detail; personnel trained in the production of that particular article would be immediately available and raw-material sources would be known.

The cost of doing this for all the multitudinous articles required by modern armies or even for the principal articles of supply would be so great as to make it impossible. What the War Department wanted to do was to have the production of all its required war material assigned to specific manufacturers and these manufacturers supplied with all available manufacturing data—blueprints, specifications, route sheets, etc., to have inspection, check and master gages, jigs and fixtures on hand, the supply of raw material and of manufacturing equipment arranged for and definite schedules of required deliveries worked out. In this way, and at a reasonable cost, the industry of the country could take up its war load quickly and with the minimum of lost motion.

It was also desired to place "educational orders" for small lots of material, the production of which involved manufacturing processes essentially different from any which were required for the production of articles of ordinary commerce, as for instance, light armor plate and military smokeless powder. Otherwise knowledge of essential arts would be lost.

In answer to the comments of Messrs. Burlingame and Blood, it was recognized that machine-tool makers, gage and small-tool manufacturers and allied industries should not be called upon to make munitions directly. It was not intended to place primary war orders with such concerns. They would be taxed to capacity to get out their regular lines in time of war and these lines were vitally essential to the prosecution of war.

Mr. Decherd's remarks gave the opportunity to point out that not every manufacturer in the country would have orders for primary war material in time of war. What the War Department had to do was to place orders for a definite amount of material with manufacturers who were best in position to make it. This would, of course, greatly stimulate industry in general and cause the placing of sub-orders and secondary contracts of all sorts. For instance, the establishment of a cafeteria in connection with a new munitions plant would create a demand for a certain amount of silverware. And of course, it was to be admitted that certain industries of a more or less non-essential character would be compelled to operate at fractional capacity, since the total industrial demand in war was immensely greater than in peace and a large number of workmen were withdrawn for the training camps.

Mr. Worker's discussion touched on the questions of securing draft exemption for skilled industrial workers, of the dilution of labor and of the redistribution of skilled labor which were very important ones. Not much had been done as yet to solve them, but they were in mind and their solution would be attempted in due course.

The preparation of a standardized contract or contracts for the entire War Department was under way by a board of officers representing all the procuring services. This would handle cost in a way which it was hoped would be satisfactory both to the Government and to the contractors.

The War Department was trying to prevent the securing of unnecessary data from and the making of unnecessary visits to plants. It was planned to have all contacts, both in peace and war, through a single office, so that the plant management would know exactly where to look for authoritative information, and would know definitely that information from any other source was not authoritative.

In answer to Mr. Blanchard, the Ordnance Department was trying to get the "kinks" out of designs and drawings in time of peace. For every article of ordnance a particular arsenal was designated as its center of manufacturing information. That arsenal produced small amounts of that article during peace and consequently developed a method of manufacture, detected errors in drawings, established tolerances, designs, gages, etc. Consequently, there would be a definite center of information to which each war manufacturer could go to get specific data to help him get into production. It was also planned to have inspection, master, and check gages in store available for every component requiring them.

It was also hoped that manufacturers holding "war orders" would get together during peace time and arrange for the interchange of helpful information.

To solve the problem of training personnel, mentioned by Mr. Henning, it was purposed to establish schools at each manufacturing arsenal immediately on the outbreak of war for the purpose of training inspectors and others in regard to the products for which each particular arsenal was the manufacturing center. These schools would be open to personnel from the manufacturers' plants, as well as to government employees.

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[1] Brown & Sharpe Mfg. Co., Providence, R. I. Mem. A.S.M.E.
[2] Pratt & Whitney, Hartford, Conn. Mem. A.S.M.E.
[3] International Silver Co., Meriden, Conn. Mem. A.S.M.E.
[4] C. H. Cowdry Machine Works, Fitchburg, Mass.
[5] S. A. Woods Machine Company, Boston, Mass. Assoc. A.S.M.E.
[6] American Engineering Company, Philadelphia, Pa. Mem. A.S.M.E.
[7] Neptune Meter Company, New York Assoc-Mem. A.S.M.E.
[8] American Metal Works, Philadelphia, Pa.
[9] Poole Engineering Co., Baltimore, Md.
[10] Du Pont Company.

The Mechanical Engineering of Management in the Metal-Working Trades

By ROBERT T. KENT,[1] MONTCLAIR, N. J.

Good mechanical engineering is shown to be essential to good management in the metal-working trades by the author of this paper. The best engineering principles must be applied to the design of the product, the arrangement of the plant, and the selection of the equipment and the methods.

THE OBJECT of this paper is to show that, in the metal-working industries, before the best management can be attained it must be preceded by good mechanical engineering. This engineering applies to the product, the plant, the equipment, and the methods.

A product designed in accordance with the principles of good engineering can be made with a minimum of machine operations, which in turn means fewer machines, lower capital investment, lower labor costs, less supervision, all of which are indications of good management. Similarly, the plant which has been adapted to its product can manufacture at less expense and with fewer problems of management than the plant not so adapted. It is obvious that the problems of management are simplified where the equipment is so selected and maintained that machine operations can be performed in a minimum of time and with few or no interruptions due to breakdowns or other delaying emergencies.

Engineering Preliminaries to Time Study

Management has in the past ten years become symbolized by certain mechanisms. Among these are time studies, routing or order-of-work schemes, stores systems, piece-work, premium, or bonus plans for wage payment, etc. These, in one form or another, may be quite necessary to the best management in the plant. Their presence, however, does not necessarily indicate that good management exists. Unless the foundation is solidly laid for the use of these mechanisms of management, their presence may do more harm than good. It is the confusing of the idea of management with the means of carrying out this idea that has been responsible for many of the so-called failures of scientific management. As an example, time study and rate setting may be cited. When the attention of manufacturers first became focused on the problems of management, time study, with piece or premium rates set therefrom, was the most spectacular phase of the new movement.

Many manufacturers seized on it as the solution of their troubles, and with little understanding of its fundamentals, put a man with a stop watch in the shop to study the operations as they then were performed, and to adjust rates of pay as a result of the studies. No attention was paid to the preliminaries that should precede the time study itself, nor to the other equally important phases of management which are necessary to the promulgation of its results. It is hardly necessary to dwell on the disastrous effects of such a policy.

Before time studies which are of any value whatever can be made in the average metal-working plant, there are many things to be done which lie in the domain of engineering and shop practice. There is little use in making time studies on operations where the methods are wrong, or the machines are in poor condition or improperly operated. Operation times from such studies are worse than useless and are sure to lead to trouble later. It should be remembered that time study is, in effect, a laboratory experiment, and that no experiment is worth while if the conditions under which it is made cannot be reproduced at any time. To insure accuracy in time studies we must have the machines in perfect order, the cutting tools made to given standards, adequate power, and high-class operation. The first three items are distinctly up to the engineer.

Assuming that the time studies have been made under the proper conditions, their results will be of little value unless these conditions are reproduced throughout the shop. Results obtained with a certain set of cutting tools, supplied with adequate power, cannot be duplicated on a machine with different tools and a deficiency of power. Here again the engineer must function before the mechanism of management may be successfully applied.

No less an authority than Frederick W. Taylor laid down the following sequence to be followed in the installation of scientific management:

a Establish a stores system
b Perfect the product
c Put the shop equipment in proper condition
d Organize and train a maintenance department
e Develop the functional organization and the routing system
f Make time studies and set rates.

It is a sorry fact that too often this sequence has been reversed, and that time studies have been started before adequate preparation for them has been made.

Another engineer prominent in management has said that if all the things that should precede time study were done, there would be little need for time study. The plant would be so far ahead of its competitors that the fixing of piece or premium rates would not give it a much greater advantage than it already had.

There is no intention in the foregoing paragraphs to decry the value of time studies. The author is a firm believer in their usefulness, but he also as firmly believes that they are capable of abuse and of giving misleading information unless the groundwork for them has first been laid. Properly made and wisely applied, they are one of the most serviceable tools that the industrial engineer can use. Under any other conditions a shop is better off without them.

The purpose of the preceding discussion has been to call attention to the amount and character of engineering work that must be done before even the best known mechanism of management can have any real and permanent value. We now propose to show how the effectiveness not only of this particular mechanism, but of all others, is affected by the engineering work that should precede their application. As was stated earlier, this engineering will affect the product, the plant and its equipment, and the methods and processes employed. The method to be followed will be the presentation of actual examples of engineering work that were found necessary preliminary to the application of the principles of scientific management, together with comments on each case.

We are well aware that the criticism will be made that the changes made and the work done in most, if not all, of the examples cited, are perfectly obvious, and that they should have been carried out in any event simply as a matter of good shop practice. The comment will be quite true, but against it must be set the fact that the changes had *not* been made, and that the improper methods had sometimes persisted for years in supposedly well-managed plants. It was only the study necessary to the adoption of more modern methods of management that brought home to those in authority that they had first to put their house in order before they could call themselves well managed.

Engineering on the Product

The design of the product exercises no little influence on the management problem. Primarily, the design must be such as to make the product readily salable in competition with the product of other manufacturers. This condition having been fulfilled, every change in design that simplifies the process of manufacture simplifies the management of the plant. It is quite obvious that a product requiring many individual parts, and a large number of sub-assemblies, is much more difficult to route through the shop than the product of few parts.

The problem of the mechanical engineer, then, is to first ascertain whether or not the design can be improved from the standpoint of fewer parts, and secondly, whether the design of the individual

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[1] Consulting Engineer. Mem. A.S.M.E.

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parts is such as to permit of the minimum number of machine operations. It must be remembered that every additional operation, be it machine or hand work, requires in the well-managed shop a job ticket, a piece or premium rate, a place on the shop schedule, and the necessary timekeeping, cost, and payroll records. Diminishing the number of operations automatically reduces the labor of management. Furthermore, such reduction in the number of operations will increase the shop capacity with a minimum of capital expenditure.

For instance: In a certain construction a very large number of rectangular plates were closely fitted into openings in a steel framework. The design of the framework was such that it was almost impossible to insure the sides of the openings being square with each other. Consequently each plate required filing and fitting to its individual opening. A radical change in the design of the framework enabled jigs to be constructed, which insured the openings being true to size and absolutely square. It was then possible to make the plates to limit gages, with the assurance that they would fit without hand work. This in turn indicated a simplification in the method of making the plates, and two machines then did more work than five. The number of fitters was reduced from three or more on each job, depending on its size, to one.

Aside from the very obvious savings in actual manufacturing cost due to the above changes, consider what they meant to the management end. The function of the management is to produce perfect salable product, and to produce it on a given date. This latter is especially true in the case of goods made for individual customer's orders. With an unknown amount of hand fitting, the time required for the completion of a job could not be forecast accurately, and a delivery date was simply a target to be aimed at, with the hope that the shop would strike within a reasonable distance of it. With the revised design, the time for every operation, including assembly, could be accurately predetermined and a delivery date set with the absolute assurance that the job would go out of the shop on that day. A reputation among his customers that a promised delivery date is the date on which the customer gets the goods is an asset of no mean value to any manufacturer. A further advantage of the changes noted was the shortening of the time that the work was in the shop. Frequently, in competitive business, the earliest delivery date will secure the order, even at a higher price. Again, the release of machines will increase the manufacturing facilities and enable orders to be taken which otherwise would be refused due to lack of capacity.

Another idea that should be kept in mind in relation to the design of the product is the possibility of substituting purchased standard parts for parts made in the shop. A case in point is the substitution of a standard ball thrust bearing for a somewhat crude and inaccurate home-made bearing. Not only was the life and ease of working of the finished equipment increased, but the cost was lower, and the machines thereby released were put to more profitable use. Furthermore, the management was relieved of the necessity of supervising some very troublesome operations.

Engineering in the Plant

Good management is frequently hampered by faulty plant arrangement. Various departments may be so located in reference to each other as to necessitate long hauls of material in process, and often much retracing of the path. Inadequate transportation facilities, such as lack of cranes and hoists, too few trucks, or trucks of improper type, add to the difficulty of moving work. It must be remembered that every movement of work in the shop increases the difficulty of supervision and management, and slows down production. A prolific field for the mechanical engineer in management is the study of the plant layout, and the arrangement of its facilities in the most convenient form. Then, too, in the various departments themselves there may be large opportunity for good engineering. Machines are often so placed that the operators are in awkward positions, that it is difficult to get work into or away from them, that the lighting is poor, that they interfere with one another, etc. All this prevents maximum production.

The question of power bears an intimate relation to production and management. This subject means more than the power plant; it means power actually available at the cutting tools. This takes us back through the machine gearing, the belts and countershafts, lineshafts and motors to the generators, engines and boilers. Unless we can deliver to the tool the full amount of power required by it, we are, from the management standpoint, going to do one of two things. We are going to set a standard of performance for the shop that it can attain only at infrequent intervals and under exceptionally favorable conditions. This means that we will fool ourselves in making schedules and promising deliveries, and we will also be in trouble with the men due to the setting of times on jobs which they cannot meet. Or, on the other hand, we will set a standard that can be met, but which is much below the standard possible with adequate power available. This is unfair to the company and may result in higher prices with consequent loss of business.

A treatise on shop maintenance is no part of this paper. Nevertheless proper maintenance not only reveals the causes of lack of power, but frequently prevents these causes from occurring. It may therefore be proper to list a few of the causes of inadequate power that have come under the author's observation, and which were removed by the establishment of a proper routine of maintenance. These included lack of tension in belts, belts too light for the machinery, excessive lineshaft friction—remedied by the substitution of roller bearings; machine gearing too light for the duty imposed on it; variations in voltage due to improper power-plant operation; the driving from the same lineshaft of machines requiring a relatively constant amount of power and of machines taking heavy drafts of power at more or less frequent intervals. In addition to these troubles in the shop itself, there have been observed actual failures to generate sufficient power due to scaled-up and dirty boilers, bad firing or improperly operated stokers, and engines with leaky or improperly set valves. Proper and adequate inspection and maintenance of the power-generating and transmission appliances will frequently postpone to the distant future the purchase of additional boilers, turbines, and generators, even in cases where these apparently are badly needed.

There is another feature of maintenance which should not pass unnoticed. Nothing upsets production so much as equipment failures. The cost of a belt breaking during working hours far exceeds the cost of repairs to the belt. It includes the cost of idle equipment, of the wages of idle mechanics while repairs are being made, and, perhaps most important of all, the loss of production and the disruption of the shop schedule. The same remarks apply to all other equipment failures. It is worthy of note that equipment failures seldom occur where regular maintenance is a part of the shop routine. Maintenance provides for preventive repairs, and insures against breakdowns. It may be set down almost as an axiom that shop maintenance is one of the fundamentals of good shop management.

Methods and Equipment

Methods and equipment are really separate subdivisions of the subject under discussion, but they are so closely interdependent that it is best to consider them together. The function of the mechanical engineer in laying the foundation for good management is first to devise the best method possible to accomplish the desired end, and then to provide the equipment which will best carry out that method.

In the case of a new shop, or a shop with ample funds for changing existing equipment, the task is comparatively simple. Where, however, the engineer is limited to the equipment on hand his ingenuity may be severely taxed. Nevertheless he can accomplish much with a comparatively small expenditure of funds. If a change in method is proposed it must stand the test that the economies effected thereby will pay the cost of the change in a reasonable time, and the new method thereafter return a profit on the investment. The return on the investment need not necessarily result from a lower cost of doing the work. It may come from releasing equipment that can be put to more profitable use.

A case in point may be cited. In the manufacture of certain war equipment two semicircular grooves were required to be cut at right angles to each other in the ends of cylindrical pieces. These were planed out to a gage in a slotter, which was so urgently needed for other work that it formed the neck of the bottle for the whole shop. The time required was 47 min. per piece. After a little

(Continued on page 307)

Night-Flying Equipment and Operation

By LTS. H. R. HARRIS[1] AND D. L. BRUNER,[1] DAYTON, OHIO

A non-mathematical discussion of a portion of the work carried on by the Engineering Division of the Air Service, which has been done more for the sake of helping to build up an aviation industry than for immediate increase in the efficiency of the airplane as a military weapon. Much of the equipment developed by the Air Service has been adopted by the Air Mail Service.

THE nation-wide publicity given to the recent four-day test of the night air mail has convinced a large portion of the general public that night flying is not only possible but practicable. Few, however, realize that the goal of successful night flying was reached only after four years of intensive experimentation on the part of the Engineering Division of the Army Air Service, on beacons and night-landing lights.

The development of a satisfactory night-landing light was started at McCook Field in 1919, the landing light being considered the primary necessity for safe night flying. The development of this one item involved the exploration of much uncharted territory. There was no question as to the source of light. The development of low-voltage direct-current generator and battery equipment for all auxiliary power requirements on airplanes was already under way and was admirably adapted to supply a reliable electric light. But preliminary flight tests were necessary to determine the amount of light necessary and the best location of the source. The first flights showed that the lights then used were too low in candlepower and gave entirely too much stray light which, reflected back by the propeller, tended to confuse the pilot. It was also found that location on the undercarriage was not bad from the lighting standpoint, but the risk of damage to the lights when landing in tall grass or stubble was too great.

Night-Landing-Light Development

To solve the problem of propeller reflection, a large number of propellers with various finishes and colors were tested on the McCook Field propeller-test rig at various speeds. A powerful flood light was set up behind the testing rig and photometric readings of the light reflected were taken. These readings showed plainly that a highly polished red mahogany finish was best, and these results were checked by flight tests later on.

The next step was to conduct flight tests with more powerful lights and it was found that a 100-ampere, 12-volt light, when used with a 13-in. silvered-glass parabolic reflector gave ample light—in fact, considerably more than was needed. Then followed a long series of laboratory and flight tests, which led to the adoption of the present Air Service landing light.

Low-voltage lamps working on the standard airplane 12-volt direct-current circuit are used in order to get a lamp with good life under continuous vibration; also to get a filament of medium concentration so that the problem of obtaining the proper beam divergence will be simplified. The reflectors used are made of metal and with parabolic sections. Metal is employed because of light weight and the necessity of avoiding complicated shock-absorbing mounts. Plain front doors are used since the desired beam is circular in cross-section and can be obtained very simply by the proper combination of filament dimensions and reflector focal length.

A lamp life of 100 hr. at normal voltage has been found necessary—not because any lamp will be burned 100 hr. in the air, but because the cold filament will break under the constant vibration experienced in flight if it does not possess great strength. In addition to requiring a minimum bench life of 100 hr., the Air Service requires that two duplicate lights be carried on every night-flying airplane and be ready for instant use at the will of the pilot. With these precautions, together with frequent inspections and lamp replacements whenever bulbs show any great amount of tungsten-oxide discoloration or filaments show marked signs of local weakness, the question of reliability need never come up.

A beam divergence of 12 deg. and a beam candlepower of 200,000 are sufficient for nearly every type of airplane now in general use and are obtained with a 9-in. reflector of 2 in. focal length mounting a 33-ampere 12-volt lamp. Screens, as shown in Fig. 1, are used to prevent the direct light from coming out at greater beam angles, although in good weather or in rain they are not necessary. In fog these screens eliminate about 50 per cent of the glare coming from the fog and are a great help when it is most important to have a good landing light.

Angular settings and beam divergence of the light are extremely important. The beam must be pointed down far enough so that with the airplane resting on its wheels and tail skid sufficient light will be thrown on the ground to enable the pilot to taxi the airplane readily. With the 'plane in a normal glide the top of the beam must be high enough to light up any obstacle to be avoided. The horizontal beam divergence must be sufficient to light up a path at least as wide as the airplane. If all landings could be made on a prepared field, with boundaries and obstacles marked, a much smaller beam divergence could be used, but a few forced landings will convince the most skeptical of the necessity for having greater beam divergence. Normal landings can be made easily with this light as objects on the ground can be readily distinguished from an altitude of 200 or 300 ft., but if a spot light to show up some landmark to be followed from a greater altitude, such as a road or a railroad, is desired, it will be found more economical to use a light of about 3 or 4 deg. divergence and of correspondingly greater candlepower.

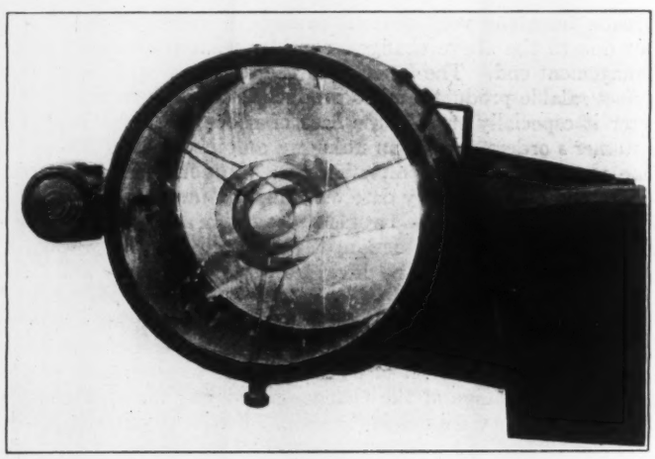

FIG. 1 WING-TIP LANDING LIGHT AND NAVIGATION LIGHT
(Note screens to cut down the beam angle.)

The location of the light on the airplane is important from the aerodynamic as well as the illuminating standpoint. The light must be located at a considerable distance from the pilot, not only to avoid the light shining on the propeller in the case of the conventional tractor type of airplane, but also to decrease the distance from an object in the beam to the edge of the beam along the pilot's line of sight. The amount of interference due to light reflected from particles of dust or moisture in the air is directly proportional to this distance. Locations on the landing gear are too exposed, as stated previously. The outer third of the lower wing is suitable as far as the light is concerned and a well-streamlined light mounted at the wing tip as in Fig. 2 is most efficient from an aerodynamic standpoint. Lights so located decrease the high speed of a standard DH-4-B only $2\frac{1}{2}$ per cent, while the same light suspended beneath the wing decreases the speed about 8 per cent, a streamlined body placed at the wing tip tending to decrease tip losses.

[1] Engineering Division, Air Service, McCook Field.

Contributed by the Aeronautic Division and presented at the Annual Meeting, New York, December 3 to 6, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Slightly abridged. All papers are subject to revision.

Larger airplanes of the multi-engined type are usually of too great wing span to permit mounting the lights at the wing tips, and in the case of the Martin Bomber at least it is very satisfactory to build the lights into the bottom of the nose of the fuselage. (Fig. 3.) This location is ahead of the propellers and is very efficient aerodynamically.

PARACHUTE FLARES

Landing lights of the type described cannot ordinarily locate a good landing field from a considerable altitude when a forced landing is imminent, and the parachute flare is the logical device for this purpose. The latest type of "Airway" magnesium flare, constructed by the Ordnance Department, will show all the terrain within gliding distance from an altitude of over 3000 ft. and burn for a sufficient period to insure that the 'plane will have landed from this altitude. It is as reliable as a flare can be made and weighs but half as much as the old Mark I flare. In case of a failure to ignite, the candle descends on the parachute without damage to any object beneath. At least two are carried for the sake of reliability. Typical installations of parachute flares are illustrated in Figs. 2 and 4.

FIG. 2 INSTALLATION ON DH-4-B OF NAVIGATION LIGHT, LANDING LIGHT, TWO TYPES OF HOLT FLARE BRACKET, AND MARK I PARACHUTE FLARE

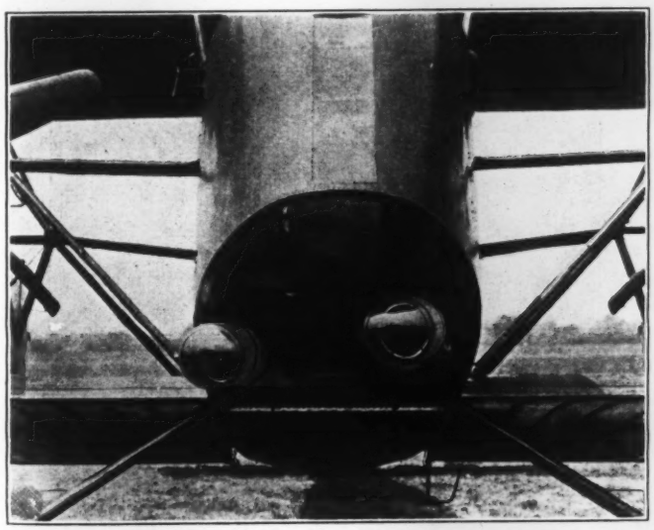

FIG. 3 LANDING LIGHTS MOUNTED ON NOSE OF MARTIN BOMBER

The landing light when used in conjunction with the parachute flare is effective in solving the forced-landing problem, and also enables a saving to be made in the lighting installation at prepared fields.

NAVIGATION LIGHTS

The navigation-light problem has been practically solved by using 24-cp. bulbs mounted in streamline-shaped transparent housings. These lights are practically non-breakable, weigh very little, and are easily mounted on the landing-light drum and on the tail of the airplane. They do not meet all the requirements of the International conventions, but probably come nearer to meeting them than do those in use by any other nation. In Fig. 2 the navigation light is shown mounted on the side of the landing light, although it is sometimes mounted above the landing light.

With the airplane-equipment development progressing satisfactorily the project of ground equipment came to the front, and the experience gained in the development of the landing lights greatly assisted in the preliminary work.

GROUND EQUIPMENT AT TERMINAL AIRDROMES

The ground equipment needed for night flying at a terminal airdrome should include boundary and obstacle lights, wind indicators, and emergency-landing lights. For boundary and obstacle lights, ordinary 50- or 75-watt incandescent lights in conventional marine fixtures as in Fig. 5, and spaced 100 to 200 ft. apart, may be used to good advantage. Boundary lights should be located high enough that the incoming pilot not only has an unobstructed view of them, but may rest assured that the airplane approaching at a normal glide to clear the boundary lights will not strike an unmarked obstacle. For marking temporary obstacles, red lanterns are fairly satisfactory.

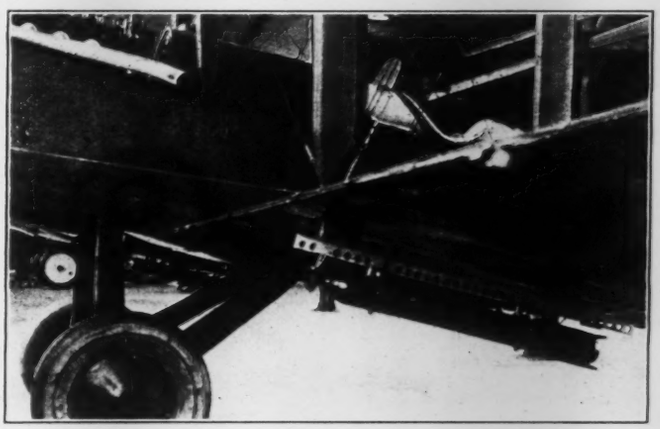

FIG. 4 INSTALLATION OF MARK I PARACHUTE FLARE

For use as a wind indicator, the conventional canvas wind cone is familiar to every pilot. If it can be successfully flood lighted it will be as good at night as in daylight. The cone possesses a distinct advantage in that it indicates wind velocity as well as direction. It is also cheap to install. Illuminated arrows and tees have been tried out to some extent, but seem hardly worth the cost.

Emergency-landing lights may consist of a row of flood lights so arranged as to light up a considerable portion of the field. Search lights are very easy to land by, if they are so arranged as not to shine directly toward the incoming 'plane. Their principal disadvantages are that they obstruct a considerable portion of the landing area, must be shifted with every change in wind direction, and require several men for their handling. One large searchlight will, if equipped with a diverging door and mounted on a hangar roof or suitable tower, not only serve as an emergency-landing light which one man can handle, but also be available for use as a beacon.

GROUND EQUIPMENT AT INTERMEDIATE FIELDS

The ground equipment at intermediate fields need consist only of boundary and obstacle lights and wind indicator. If the corners of the field be well marked and approaches good, many of the side lights may be omitted and costs correspondingly decreased. If electrical energy is not available, gas lights similar to the well-known traffic beacon may be substituted to good advantage. At least three of the gas lights are required at each corner of the field to show the shape of the field distinctly. These lights are

fairly satisfactory as boundary lights, but have exceedingly low visibility for beacon purposes and cannot be considered for that work. Special gas beacons (Fig. 6) have also been tried but with unsatisfactory results. It is believed, however, that the gas-flasher type for boundary markers has certain distinct advantages on account of its flashing charactersitics and the tendency of the pilot's eye to note any moving light.

Landing an airplane in a field outlined by boundary lights with the aid of the Air Service night-landing lights is a comparatively easy task and is approached in the same way as the ordinary daylight landing. Settling in or stalling is absolutely unnecessary; in fact, it is often advantageous to come in on a rather steep glide and pull out rather sharply as excess speed gives the pilot more chance to correct any mistake in handling the 'plane before it is necessary to land.

BEACONS FOR CROSS-COUNTRY FLYING

To make night flying a commercial possibility, aerial lighthouses which enable the pilot of a night-flying airplane to make a long cross-country flight without dead reckoning are also necessary. In early experimental work on this type of equipment, several foreign beacons were tested. These were marvelous examples of the workman's skill, and entailed an elaborate and expensive system of lenses which was considered by the designers as giving a lighting characteristic of ideal shape. But the necessary candlepower was apparently figured out on a basis of a perfectly clear atmosphere, which, of course, is never found; and one of the best of these devices gave a maximum visible range under favorable weather

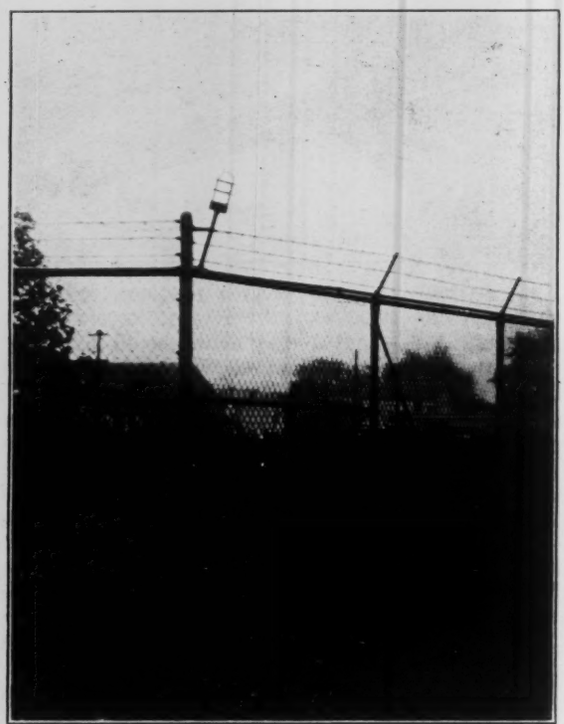

FIG. 5 METHOD OF MOUNTING BOUNDARY LIGHTS ON FENCE

conditions of 8 miles, while the flashing lights of the business district of Dayton were visible under the same weather conditions for over 30 miles.

The early "wobbling" beacons of American manufacture went to the other extreme and threw upward a light beam of tremendous candlepower, assuming that reflection from particles of dust and moisture in the air or clouds would give the necessary light in the horizontal plane.

To investigate the flashing-sign type of beacon the McCook Field water tower was painted white and flood lighted. An ordinary sign flasher in the circuit made this device quite useful at moderate distances, and under favorable weather conditions this flashing beacon has been picked up at 20 miles, even though the city lights were all around it.

Meanwhile, the personnel of the Engineering Division were engaged in using searchlights in night survey work and incidentally getting valuable information as to the range of visibility of lights of various kinds, including the high-intensity arc searchlight. Two American searchlight manufacturers coöperated by constructing, experimentally, beacon lights which utilized a searchlight beam that waved to and fro at angles from 45 deg. to 90 deg. above the horizon. These proved to be useful only for ranges up to 15 miles and compared very unfavorably with the water-tower beacon.

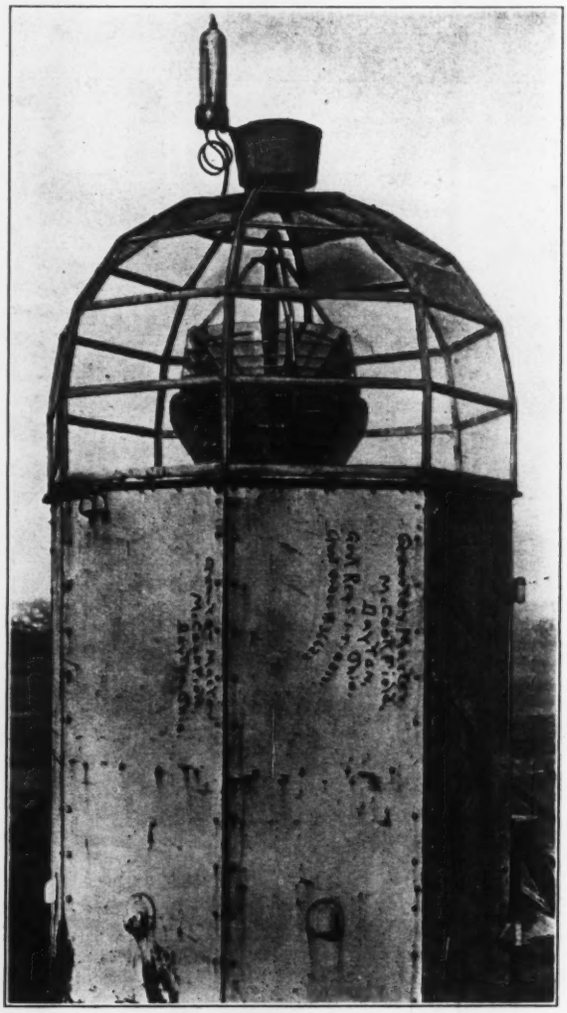

FIG. 6 UNSATISFACTORY TYPE OF GAS BEACON

An analysis of all test results up to this time showed conclusively that:

1 An apparent beam candlepower running up into the millions is necessary to get good results at long range
2 The atmospheric reflection and stray light from a source of high light intensity was sufficient to give the necessary visibility at short distances out of the direct beam.

It remained, therefore, to apply only the principle that the best way to see a light is to look at it when it is pointing toward one and use a rotating horizontal beam of light for a beacon. Working on this principle, beacons which are visible at ranges up to 150 miles under favorable conditions and up to 30 miles in bad weather were developed at very little expense, obsolete 36-in. coast-defense searchlights being remodeled for the purpose.

The large initial cost of the new searchlights and their accessories, together with the necessity of having an attendant constantly on the job, limits the use of this type of beacon to terminal airdromes, and the most economical beacon for airway use is the rotating incandescent type shown in Fig. 7, which is similar to the large beacon except that it employs a large incandescent light instead of

the arc lamp. This incandescent beacon requires only one kilowatt of electrical energy for its operation, and if there are no electrical supply lines in its vicinity it may be operated from an ordinary farm-lighting plant at surprisingly low cost. The appearance of this type of beacon in the distance can best be described as being that of a great luminous winking eye. At short ranges, owing to the small beam angle and the low setting, it appears as a long ray of light lazily revolving about a central bright spot and always passing beneath the airplane, if any considerable altitude is being maintained.

It seems impossible to give mathematical expression to the range

FIG. 7 FIRST ROTATING INCANDESCENT BEACON

of beacons, owing to the difficulty of measuring the beam candlepower at any time, and owing to the great variability of dust and moisture content of the air.

The best speed of rotation has been found to be that at which the duration of the flash is from $^1/_{14}$ sec. to $^1/_{18}$ sec. and is therefore a direct function of the beam divergence. The best location for a beacon light is naturally the highest, both because of ground-fog interference and the curvature of the earth. The most satisfactory angular setting of a beacon is an elevation of half the beam divergence, as this permits the bottom of the beam to barely clear surrounding obstacles, and, at the same time decreases the altitude necessary to get in the beam at a distance.

Beacon lights of lower candlepower can be built and operated for less money; but one of the principal advantages of having a continuous chain of beacons will then be lost. It is impossible for a pilot to leave his course temporarily to avoid a bad storm and return to it later with the certainty that he will have several minutes to pick up his course. With the 25-mile spacing of beacons now under development, which beacons are visible for 15 miles under bad weather conditions, the intersecting range circles (Fig. 8) give an illuminated path several miles wide from one end of the airway to the other, and help the pilot much more than a greater number of smaller lights.

THE DAYTON-COLUMBUS NIGHT AIRWAY

Following this experimental work, on July 2, 1923, the first regular night-airway line in the world was established by the Engineering Division of the U. S. Air Service between Dayton and Columbus, Ohio, a distance of 72 miles. The line was established for the purpose of testing out night-flying equipment as well as for the purpose of discovering through pilots' reports the difficulties encountered and improvements that might be desirable. Between July 2 and August 13, inclusive, 29 trips were scheduled. Of this number 25 were completed, 2 of them being postponed on account of weather.

In the course of these tests an extremely interesting and very important aid to navigation was found in the steady stream of automobile headlights along the National Highway. This was so important a landmark that nearly all the trips were made a little to the north of the air line between McCook Field and Norton Field, Columbus, following the highway from Columbus to Springfield.

The lights of the various cities, towns, and villages along the route were of considerable assistance as landmarks, provided the pilot was at all times familiar with his approximate location. Small villages have very much the same outline of lights, and unless the pilot keeps a careful check from point to point, he is likely to become confused by them. This confusion may ultimately lead to complete loss of course. Important and more useful landmarks along any night route are the lights of the larger towns and cities, which are visible at a considerable distance and always have definite outlines which can be recognized provided an altitude of 1000 ft. is attainable and the pilot is familiar with the arrangement of that particular city.

Considerable effort was expended during the night tests to photograph cities from an airplane at night in order to make accurate night charts, but with very indifferent success on account of the fact that time exposure was necessary and vibration of the airplane blurred the negative. It is believed, however, that satisfactory photographs can be secured from dirigibles or kite balloons and that night maps must be prepared by these means in the next few years. An alternative method would be to develop satisfactory sensitive negatives for practically instantaneous night exposures. Ordinarily two sets of chart photographs will be required, one set taken before midnight and the second set after, since most cities

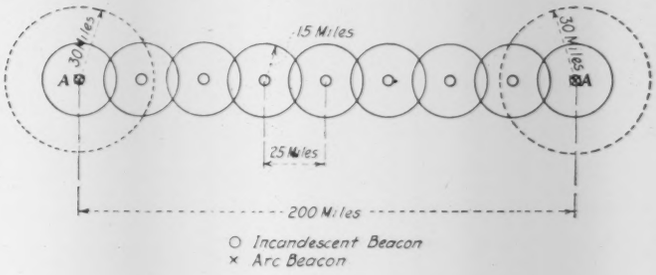

FIG. 8 AIRWAY BEACON SYSTEM CHART

(Ranges shown are for conditions of low visibility. Arc beacons used in emergency or as emergency-landing lights only. Terminal airdromes with arc and incandescent beacons located at 200-mile intervals *A-A*. Emergency airdromes with incandescent beacons located at 25-mile intervals)

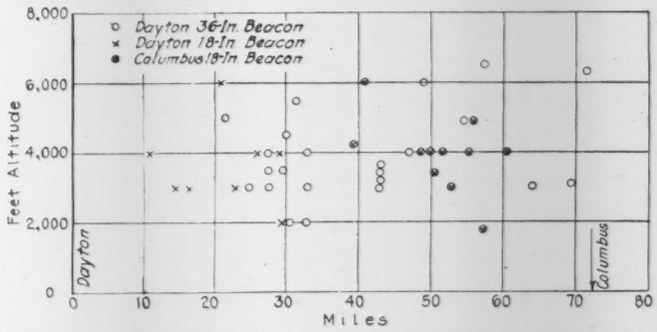

FIG. 9 OBSERVATIONS DURING NIGHT FLIGHTS BETWEEN DAYTON AND COLUMBUS AT VARYING ALTITUDES AND VISIBILITIES

reduce their street illumination considerably at midnight and the entire outline may change.

Experiments carried on with a view to illuminating the name of a locality to be read from the air at night, have shown that the only satisfactory method is by outlining the letters or symbols in electric bulbs with a considerable brilliancy. Since all cities have a large number of electric advertising signs that are in operation at night it is somewhat difficult to determine the best location for night markers.

Very interesting data were secured during the night flights between Dayton and Columbus, which flights were carried on under various conditions of visibility and at altitudes ranging from 1500 to 6500 ft. Fig. 9, a chart of the observations made at various altitudes, shows that, irrespective of altitude, the 36-in. arc beacon is visible for an average of 40.3 miles, with a worst visibility of 21 miles. The 18-inch incandescent beacon at McCook Field is visible for an average of 21.1 miles, with a worst visibility of 11 miles. This would indicate that an 18-in. beacon should be installed every 15 or 20 miles in order to give an absolute path under extreme

conditions for airway operations. The distinct advantage of the 18-in. light over the 36-in. light is the fact that it is an automatic incandescent device requiring no attention excepting a weekly inspection. On the other hand, the 36-in. light is an arc light which requires constant attendance and a manual carbon replacement at intervals of about two hours.

Experiments are to be carried on in the near future to determine whether a more powerful incandescent light with a proposed larger diameter cannot be arranged to give even better results than have been secured to date with the 18-in. light. It is believed that fields and lights may then be located at 25-mile intervals as shown in Fig. 8.

INTERMEDIATE LANDING FIELDS

On the normal airway, emergency fields situated every 25 miles are sufficiently close to enable a pilot to limp in to a marked landing field in case of partial motor failure, and this checks up very well with the minimum visibility of the 18-in. beacon discovered in the tests run to date as regards maintenance of an overlapping light-beam arrangement. For marking emergency fields at points where electric current is not constantly available, various farm-lighting sets are now being tested at an emergency field which has been established at London, Ohio.

Considerable difficulty has been encountered in properly indicating the position and altitude of obstacles such as trees, pole lines, etc., surrounding night-landing fields. In small fields the altitude of approach is usually a determining factor in the ability of the airplane to land. Single light sources without definite reference points are worthless except to determine location, and it has been found necessary to flood light such obstacles as cannot be removed in order that the relative size of the shadows and lights coming from the obstacles may indicate its altitude and extent.

KEEPING THE PILOT "DARK-ACCUSTOMED"

In order to keep down the cost of a lighting system the pilot's eyes should remain "dark-accustomed." The amount of illumination required to give him the necessary information is then comparatively small. Moreover, even on the darkest nights the natural light is sufficient to tell the experienced pilot a great deal provided it is not in competition with artificial light of high intensity. During a night flight all unnecessary lights on the airplane should be extinguished. Necessary instruments should be dimly lighted with luminous paint, or if other sources of light are used; they should be dimmed down to the minimum that will enable the instruments to be read. Bright lights in or near the pilot's cockpit are a great help in preparing for the flight, but should be turned off for a sufficient period before the start to enable the pilot's eyes to become "dark-accustomed." Exhaust manifolds which glow or show flame should be avoided. Also, on the take-off from a prepared airdrome all lights, except small boundary or obstacle lights to show the limits of the field or dangerous obstacles, should be turned off.

In view of the foregoing requirements the authors believe—

CONCLUSIONS

a That all night-flying airplanes should be required to carry:
  1 Two wing-tip landing lights
  2 Two parachute flares
  3 One set of navigation lights
  4 One hand flashlight or other independent source of light which can be used for signaling purposes.

b That each terminal airdrome should be provided with:
  1 A combined emergency beacon and landing light giving a minimum beam candlepower of 250,000,000
  2 A complete set of boundary and obstacle lights
  3 An illuminated wind cone.

c That each intermediate landing field be provided with:
  1 Boundary and obstacle lights
  2 An illuminated wind cone.

d That incandescent beacon lights of the horizontal rotating type be located at or near terminal airdromes and intermediate landing fields, which ought to be located at no greater intervals than 25 miles along the course.

It is not to be thought that the development of night-flying equipment has been completed, but it is believed that the Engineering Division of the U. S. Air Service has developed apparatus and methods which make night flying not only possible but reasonably safe and reliable. In addition to developing the night-flying equipment now in use by the Army Air Service and Air Mail, McCook Field has, according to latest advices from overseas, changed the whole trend of European night-flying development.

Discussion on the Solid-Injection Oil Engine

(*Continued from page 258*)

of the liquid proper. This air was further augmented by such additional air as might be trapped in the pump parts and discharge pipe. In smaller high-speed fuel pumps these combined air effects seriously interfered with the proper functioning of the injection process, and in extreme cases might cause continued injection of fuel throughout the expansion stroke.

The maintenance of high pressure behind the nozzle during the entire period of fuel injection, wrote Mr. Illmer, was a most effective means for obtaining an extremely fine atomized condition of the fuel. Such surfacing was essential for rapid and perfect mixing of the fuel with all of the available air. Unless suitable means were provided to meet this need, the expected results would not be competitive with those obtained by air-injection methods.

Effective turbulence was also necessary to drive the finely divided particles away from the nozzle and cause them to be uniformly mixed throughout the available air. Perfect atomization, combined with ample penetration of the fuel, were believed to be essential for smokeless and economical combustion in airless-injection oil engines. Fine atomization, unaccompanied by adequate turbulence, would result in pocketed or localized combustion, no matter how thoroughly the fuel might be broken up or surfaced.

Mr. Illmer had found the jet nozzle to give best results as regarded fuel economy and maximum output per unit of piston displacement. The jet should impinge on the hot surface of the piston. When properly arranged it was possible to make the highly atomized fuel charge penetrate and thoroughly mix with all parts of the available air. Such injected fuel ignited almost instantaneously in a manner similar to that of a full-Diesel engine.

The size of nozzle hole was important in the satisfactory operation of direct-injection oil engines. A minimum diameter of $^1/_{64}$ in. was necessary to prevent clogging the nozzle. It was Mr. Illmer's experience that a fuel-pump pressure of from 3000 to 5000 lb. per sq. in. was required to obtain satisfactory atomization and penetration of the more common grades of fuel oils.

Furthermore, it was important to maintain a correct ratio of air in which to burn a given injection of atomized fuel. These and similar points had been covered in Mr. Illmer's paper entitled Porting and Charging of Two-Stroke Oil Engines.[1]

Another important point was the prevention of dribble at the nozzle after the injection period had terminated. For best results, the pressure behind the nozzle should drop almost instantly to atmospheric pressure by venting the nozzle or discharge pipe back into a relieved pump chamber. Unless the pipe line and the entire system were sharply relieved of pressure, the gradual expansion of air in the oil discharge passage was likely to cause some of the fuel oil to dribble into the expanding cylinder gases.

S. A. Hadley[2] wrote that the author nowhere touched on the question of suitable fuels for the solid-injection engine. It would be interesting to know what he considered were the characteristics of a suitable fuel, its viscosity limits and the results of preheating the fuel to various temperatures. A rather extensive observation of various types of solid-injection engines seemed to show that this type of engine had a much narrower range for suitable fuels than the air-injection engine. Further discussion of this point would be very interesting.

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[1] Trans., A.S.M.E., vol. 43, p. 649.

[2] Dist. Mgr., McIntosh & Seymour Corp., Auburn, N. Y. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Shaft Whipping

By DR. B. L. NEWKIRK[1]

THE article forming the subject of the present abstract is interesting both because of the results obtained and because it presents an example of the methods employed in a very large organization, such as the General Electric Co., for the solution of a troublesome problem, and shows how by the coöperation various departments, engineering knowledge and equipment of great variety and the highest quality are employed. This example of intensified research is significant in showing the advantages that lie with the very large organizations when handled on the American principle of coöperation between the departments. It is also of interest in that the results of the investigation when obtained were not kept confidential but were given out to the world fully.

It has been observed at the works of the General Electric Co. that blast-furnace compressors as well as certain other machines were subject to occasional fits of more or less violent vibration. During these disturbances, the nature and cause of which were unknown, the shaft would vibrate at a low frequency which in some instances could be followed by the eye. This was called by shopmen and engineers "shaft whipping."

The whipping motion as observed casually appeared to be an oscillation of the shaft of rather low frequency, certainly much lower than the speed at which the shaft was running. This oscillation of the shaft set the whole machine into vibration. The phenomenon was known to occur only at speeds well above the critical speeds of the rotors in question. For example, rotors having critical speeds around 1000 r.p.m. would not whip at speeds below 2500 r.p.m., but the whipping might occur at any higher speed. The vibration was in some cases very gentle, so that it was scarcely noticed; in other cases the vibration was severe, necessitating the shutting down of the machine. No machine could be counted upon always to whip, or not to whip. Refinement of balance did not reduce this form of vibration. The whipping tendency seemed to depend upon conditions of temperature and humidity of the air. The steadiness of the blowing action was also an important factor; that is, with the compressor working against high furnace pressure, near the breakdown point of the machine whipping was likely to occur, but it did not always appear under these conditions. The alignment of the machine and conditions at the bearings were known to influence the occurrence of this vibration. It was customary to adjust the ball-seated bearing liners with care, and special precautions were taken to prevent distortion of alignment of the machine by steam pipes or otherwise. When whipping occurred in spite of these and other precautions, it would usually be stopped temporarily by driving wedges at one point or another under the compressor foot to change slightly the alignment of the points of support. It was known that the fit of the impellers and packing sleeves on the shaft had much to do with the whipping tendencies of the rotor, any long sleeve gripping the shaft at the two ends of the sleeve being sure to produce whipping.

Analysis of the Motion

The first effort was directed toward analysis of the motion. To this end two methods were employed. In one a small coil with an iron core is embedded in an iron block and the block is bolted in a position near the shaft with the end of the coil $^1/_{16}$ in. more or less away from the shaft. A small direct current supplied by a battery is then passed through the coil and any oscillation of the shaft, bringing it nearer or further away from the coil, changes the magnetic flux and varies the current in the coil. This variation is recorded by an oscillograph. By this method it was found that the whipping motion was a more or less regular whirl of the shaft and that it occurred at a constant frequency independent of the speed of the rotor. This frequency was identical with the frequency of the whirl at critical speed.

Another method of studying involved the use of a pointer attached to the end of a shaft. The tip of this pointer was illuminated by means of an arc lamp and the motion of this tip was photographed with a motion-picture camera, making about 16 exposures, each of about $^1/_{36}$ sec. in length and with an interval of a little more than $^1/_{36}$ sec. between exposures. These pictures

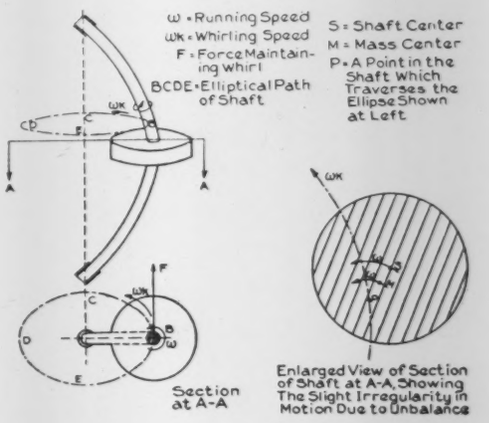
ω = Running Speed
ωk = Whirling Speed
F = Force Maintaining Whirl
BCDE = Elliptical Path of Shaft
S = Shaft Center
M = Mass Center
P = A Point in the Shaft Which Traverses the Ellipse Shown at Left
Section at A-A
Enlarged View of Section of Shaft at A-A, Showing The Slight Irregularity in Motion Due to Unbalance

FIG. 1 DIAGRAMMATIC REPRESENTATION OF SHAFT WHIPPING

Whipping is a whirling motion of the shaft, shown in this diagram in greatly exaggerated form. The whirling speed is equal to the critical speed of the rotor and the running speed must be higher than the critical speed.

brought out very clearly the fact that the whipping motion in the case of this model was a whirling nearly circular in form, occurring at a rate of about 2700 whirls per minute and that this rate of whirl was independent of the speed at which the model was running. (It should be noted, however, that one of the critical speeds of the model is 2700 r.p.m.) The same kinds of tests were applied to other models and to three different compressors and in all cases it appeared that the whipping motion was a whirling of the shaft occurring with a period equal to that of the critical speed whirl of the rotor and that the period of whirling was independent of the speed at which the rotor was running. It was also determined that the direction of whirling agrees with the direction of rotation.

It was then clear that the whipping motion of the shaft is approximately that indicated by the ordinary solution of the equations for the undamped motion of a shaft. For the convenience of those who may not be familiar with the literature of the subject, an outline of the solution is given in an appendix to the original article.

This follows the treatment given by August Föppl in the fourth volume of his work on technical mechanics. It indicates that neglecting damping action, a vertical shaft carrying one disk, such that the weight of the shaft can be neglected in comparison, may revolve as indicated in Fig. 1. This diagram shows a certain point P in the shaft traversing an ellipse at a certain constant angular velocity ωk, while the shaft and disk are rotating about P at some other angular velocity ω. In the discussion of this solution, it is usually assumed that the whirling motion shown large in the figure (motion of P) is damped out quickly and that

[1] Research Laboratory, General Electric Co., Schenectady, N. Y.

the superposed small whirling (about P) due to unbalance remains. Whipping, then, as the term is being used, is a case in which the larger whirling does not damp out but builds up to the point where it is the major disturbance, and the effect of the unbalance is negligible in comparison. Presumably some force indicated by the arrow F in the figure acted to build up the motion. It was observed that it built up gradually and that usually some jar was necessary to start it. It was the opinion that a jar was necessary to start the whipping in all cases and that in those cases in which the whip was apparently self-starting, the small jars incident to running were responsible.

THEORY

At this stage of the investigation A. L. Kimball, Jr., a member of the staff of the General Electric Co., suggested that the internal viscosity of the metal of the shaft might furnish the stimulus for

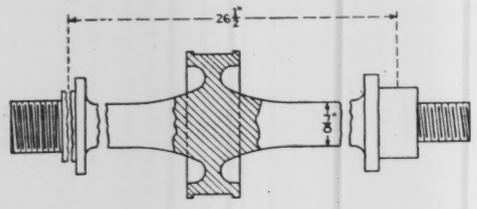

FIG. 2 SHAFT WITH SPECIAL HUB DESIGNED TO BE FREE FROM THE CRAMPING ACTION

the whirling. An analysis made at the same time tended to indicate, however, that cramping sleeves or impellers shrunk or pressed on the shaft produce an effect similar to that of internal friction of the shaft metal and subsequent tests have shown that shaft cramping rather than internal friction of the metal of the shaft is responsible for the disturbance.

The analysis itself is not suitable for abstracting. It would appear, however, that it shows that when a vertical shaft runs true about its axis, there is no stimulus to whipping, due to cramping or internal friction since the deflection BO is zero. Some blow or other disturbance is necessary to produce a deflection and so initiate the whipping action. Once started the shaft whirls in an elliptical path, there is a deflection BO at each point of the path and the stimulating force F, Fig. 1, is present. Similarly when a horizontal shaft rotates in its static deflection curve, slightly modified by the effect of cramping or internal friction as has been explained, equilibrium exists and there is no stimulus to whipping, but any disturbance brings the whipping stimulus into existence and the whirl occurs about the curve in which the shaft would run quietly if it were not whipping.

It should be noted that the expression "stimulus to whipping" as used throughout this article refers to the assumed force F, Fig. 1, and not to the blow or jar or other disturbance which this argument indicates should be necessary to produce a deflection, bringing the force F into play and initiating the whipping action.

In order to determine whether internal friction of the metal or cramping at a fit was responsible for the whipping, the following test was made. A shaft was prepared of the section shown in Fig. 2, and a disk was mounted upon this shaft with a tight shrink fit. It was assumed that the unit stress (and consequently the deformation) in the metal of the shaft being very low where the hub is in contact with the disk, the tendency to slip between the shaft and the disk in this case would be less than the friction resistance to slipping, so that this stimulus to whipping would be eliminated, leaving the internal friction presumably the same as in other models. This particular model had a shaft $^7/_8$ in. in diameter except at the hub, a span of $26^1/_2$ in. between bearing centers, and a disk weighing 85 lb. The bearings were SKF self-aligning No. 407. The critical speed was 1090 r.p.m. It was impossible to make this model whip, although it was run at nearly nine times its critical speed. To test the effect of a cramping fit in producing whipping a cramping device, shown in the original paper, was prepared. This is simply a collar with a chuck at each end to grip the shaft at two points about 7 in. apart. With this device the model whipped violently at all speeds above the critical speed. These and other tests convinced the author and his associates that cramping fits rather than internal friction of the shaft metal are accountable for whipping.

It was found repeatedly in the course of tests that any stimulus to vibration of the shaft which occurs in the frequency of the natural vibration of the shaft (i.e., the frequency of the critical speed) will produce vibration of the shaft independently of the speed at which the rotor is running; which, of course, it should do according to theory. It is therefore not unlikely that whipping, by which is meant vibration or whirling at the critical frequency when the rotor is running at some other speed, may be and is sometimes produced by other causes than a cramping fit on the shaft. The view at present is, however, that the difficulty with the blast-furnace compressors has been due to the cramping fits.

It was found that whipping produced in this way would not occur at speeds below the critical speed of the rotor. Where the tendency to whip was very strong as, for example, when the cramping device was used, the whipping would begin of its own accord when the rotor was running at any speed above the critical speed. The whipping could be quieted by steadying the shaft near the middle point, but as soon as the restraint was removed whipping would build up again until the shaft struck the guard.

MEANS TO PREVENT WHIPPING

Early in this investigation H. D. Taylor, assistant to the author, found that any looseness of the bearing standards or of the clamps which held the model down to the iron floor in the factory where the tests were made had a strong tendency to prevent whipping. It was found also that flexibility of the bearing supports tended to prevent whipping. It was found also that flexibility of the bearing supports tended to prevent whipping. An effort was made to decide whether flexibility only of the supports would prevent whipping or whether some damping action was necessary in addition. To this end a holder was prepared to take the place of one of the bearing standards and supply flexibility of the bearing with the minimum of damping frictional resistance to motion. It was found that with the bearing supported in this holder, whipping would not occur provided the rod was clamped with sufficient free length. (In general, a free length of 6 or 8 in. with a corresponding deflection at the bearing of 20 to 45 mils was sufficient to prevent a model from whipping.)

W. E. Ver Planck, engineer in charge of compressor design, prepared spring bearings for several of the compressors. These were so made that an inner liner of the bearing was spring supported, and the designs included a device to introduce frictional resistance to any motion of the inner liner relative to the bearing standard. A series of tests were made with bearings of this sort at the compressor end of a three-bearing turbo-compressor rotor. In these tests heavy, light, and intermediate springs were tested, also frictional damping of different amounts. In no case could the compressor with a spring bearing be made to whip. It was found also that damping was not necessary except as it occurred incidentally in the operation of the spring bearing. Subsequent to these tests a number of machines in the field have been equipped with spring bearings at the compressor end and these are running without difficulty.

Hard, medium, and soft springs were tried in the spring bearing, also the use of damping friction in various degrees. The tests showed that with solid bearings this unit could be made to whip at will, but with the spring bearing it would not whip; also that so far as could be observed no damping friction was necessary to prevent the whipping.

The original article shows a photograph of the pointer tip made with the special motion-picture camera, modified to give about $4^1/_2$ diameters enlargement. The interval between exposures is about $^1/_{16}$ sec. Three jars due to pulsations are recorded on this strip of film. Not only did these jars fail to start whipping but the shaft quieted down within $^1/_{16}$ sec. after friction was applied. This and numerous related tests show beyond the shadow of a doubt that the spring bearing actually prevents the occurrence of the shaft whirl or vibration which has been called whipping.

In the light of this study of shaft whipping the occurrence and characteristics of whipping in blast-furnace compressors as described in the first section of this article may be explained as follows:

The belief that cramping sleeves or impeller hubs result in a

tendency to whip was fully confirmed and explained. That the compressors would not whip at speeds lower than two or two and a half times the critical indicates that the whipping tendency in these rotors is not strong and that the stimulus, which in the case of the blast-furnace compressors evidently increases with the speed, is not sufficient to maintain the whip at lower speeds. Variation in the degree of shaft cramping accounts for the fact that some machines whip more severely than others. Temperature conditions affect the alignment and tightness of joints in the compressor. Distortion of alignment by any other means affects the tightness of joints and the reactions at the supports of the compressor. These determine the frictional or damping resistance to vibration and so change the balance between the whipping tendency and the damping tendency as disclosed in the tests. The importance of conditions at the bearings was also confirmed by the tests, which showed that either looseness or flexibility at a bearing prevented whipping. That unsteadiness of the blowing action should precipitate whipping is to be expected, since such unsteadiness subjects the shaft to shocks due to turbulence of the air. The tests indicated that a shock is certainly efficacious and probably necessary to start whipping. Driving wedges under the foot of the compressor stopped the whipping probably by distorting the machine or correcting a distortion, and so changing the flexibility at the bearing, or the minute working at the joints, thus giving the damping tendencies the preponderance over the stimulus to whipping.

In conclusion the author points out that the work was done at the request of W. E. Ver Planck, designing engineer, Compressor Section, Turbine Engineering Department. Rapid progress was made possible by the coöperation and interest of numerous members of the General Electric organization who are named in the original article. An appendix contains an exposition of A. L. Kimball, Jr.'s theory, of the cause of shaft whipping. (*General Electric Review*, vol. 27, no. 3, Mar., 1924, pp. 169–178, 13 figs., *cA*)

Short Abstracts of the Month

AERONAUTICS (See also Internal-Combustion Engineering)

The British Aircraft Carrier "Hermes"

ALTHOUGH of not more than 10,950 tons displacement, this vessel has a flight deck with an overall length of 598 ft. and a breadth of 90 ft. She is propelled by Parsons geared turbines of 40,000 shaft hp., and a speed of 25 knots was easily attained on her steam trials. Twenty airplanes or seaplanes can be stowed in the hangers below deck, where there are well-equipped shops for the repair and adjustment of aircraft and their engines. Magazines are also provided for torpedoes and bombs. Six 6-in. guns are mounted in sponsons along the broadside, and on the flight deck two 4-in. anti-aircraft guns are placed before and two abaft the superstructure. With her full quota of Royal Navy and R.A.F. personnel on board, the *Hermes* has a complement of 664. She is under the command of Captain the Hon. A. Stopford, who was appointed to her early last year. On commissioning she will relieve the *Argus*, the "funnel-less" aircraft carrier, which has been attached to the Atlantic Fleet since 1919. (*The Engineer*, vol. 137, no. 3555, Feb. 15, 1924, p. 163, *d*)

The Gibbons Airplane Landing and Launching Device

THE really new feature of this device is the means of retarding the 'plane after landing. For this purpose means have been provided for greatly increasing the friction forces on the wheels and skid, and another force has been added by causing the 'plane to land up an incline.

The retarding force due to the incline is a function of the angle of the platform and the weight of the 'plane. For an angle of 15 deg. it amounts to a little over one-quarter the weight of the 'plane, which is an appreciable force. Landing up an incline has some other advantages also. It throws the center of gravity further back relative to the wheels, thus reducing the tendency to nose over, and causes more of the weight of the 'plane to be carried by the tail skid, which has a much higher coefficient of friction than the wheels. This again tends to slow up the 'plane.

The next thing that has been done in the landing device is to remove the bank of air under the wings which causes the 'plane to float just before it touches the ground due to the air banked up between the wings and the ground. On the landing platform the floor has been made in the form of a grid and the bank of air is removed by drawing air down through the floor by means of large ventilating fans. Additional retarding effect is secured by means of flexible steel cables stretched across the platform beginning 75 or 80 ft. from the approaching end every 16 in. and located about 8 in. above the floor.

These cables are held in tension by heavy steel springs. When the 'plane lands first the wheels strike each one of the cables and then the tail skid, each in turn forcing the cable through an arc of a circle to the floor against the action of springs.

It is said that as a result of all these various retarding devices a 'plane landing at 60 m.p.h. which would run between 600 and 700 ft. when landing on an ordinary field will run only 125 ft. on the landing platform. The platform is fitted with various safety devices. (*Aviation*, vol. 16, no. 12, Mar. 24, 1924, pp. 308–309, *d*)

AIR ENGINEERING

Experiments on the Distribution of Air in Centrifugal Fans and on Reëntry Phenomena

THE purpose of the paper here abstracted is to record experiments made at the Heriot-Watt College, Edinburgh, and at the Wellesley Colliery, Fife, bearing upon the manner in which a centrifugal fan of the drum type deals with the air it discharges. The author has endeavored to show how uneven is the distribution of air passing through the wheel and to direct attention to the different forms of reëntry of air.

Observations on the passage of confetti through a fan proved that the incoming air strikes with violence against the curved boss of the fan, the effect being more pronounced the higher the velocity of the air. The air stream striking the boss will tend to rebound and be deflected into the inner end of the blades.

In order to ascertain the distribution of air across the width, three blades of each of the five fans were selected, the blades being 120 deg. apart, and their surfaces were coated with an adhesive substance. Uniformly sized confetti of thin paper were introduced, a few at a time, into the ingoing air, precautions being taken to insure that they were evenly distributed in the air. Some of the confetti stuck to the treated blades. The number of pieces adhering to each inch of fan width (each 6 in. in the case of the Wellesley fan) was counted. Every such test was repeated twelve times before altering the speed or resistance. Mean values made it possible to plot graphs showing the proportion of the total air delivery which flows through each section of the width with the fans running in the casing. Other tests were made with the fans running in the open, but in almost every case the greater part of the air discharges near the back of the fan (or near the central partition of the double-inlet type) and very little near the inlet or inlets of the fan.

The original article shows a patented arrangement (Harter's ring deflector) which is intended to divide and direct the air by means of plane partitions and thus improve its distribution along the blades.

As regards reëntry, it is stated that the low viscosity and low inertia of air are factors increasing the likelihood of its reëntry in centrifugal fans. The paper discusses the reëntry between the blades and longitudinal reëntry, also centripetal reëntry and reentry from the casing into the fan only.

As regards reëntry between the blades, it is started that it is probably a marked factor in certain types of fans. It may be expected that this form of reëntry will be proportionately larger when the fan is delivering less than the quantity of air for which it was designed. The shape of the passage between two adjacent blades is clearly the important factor here. This question was carefully studied in the design of the Rateau fan.

Longitudinal reëntry can be shown to exist when the fan is work-

ing under normal conditions, but can most easily be demonstrated when the fan is made to run out of its casing in the open. Longitudinal reëntry can be avoided by guiding the air gradually from the axial to the radial direction in the manner exemplified in the Rateau machine.

Centripetal reëntry is evident particularly in a fan fitted with shallow blades, the tips of which turn downward, especially when such a fan is delivering a smaller volume of air than it was designed for. The importance of the casing in this connection is greater than is generally admitted. As tests made on a Sirocco fan show the function of the casing is not merely to gather the air passing from the wheel and lead it smoothly to the évasé, it needs to be so designed as to prevent centripetal reëntry over the fans working range of volume. The addition of a slightly expanding diversifier ring interposed between the wheel and the casing has much in its favor as a probable preventive of centripetal reëntry. (Paper by Prof. Henry Briggs and Jas. N. Williamson, read Feb. 16, 1924 before the North of England Institute of Mining and Mechanical Engineers. Abstracted through *Iron and Coal Trades Review*, vol. 108, no. 2921, Feb. 22, 1924, pp. 302–303, 14 figs., *eA*)

BUREAU OF STANDARDS (See Testing and Measurements)

ENGINEERING MATERIALS (See Testing and Measurements)

FUELS AND FIRING

The Flow of Gases in Furnaces as a Function of Their Temperature Drop

THIS paper deals with the application of the formula of Groume-Grjimailo and Yesmann to furnace design. Essentially the basic idea of these two physicists is similar to the flow of water over a broad-crested weir, except that the gas stream is inverted. Upon this hypothesis they produced by the application of the law of hydraulics their formula—

$$Q = B\sqrt{\frac{h^3 \times t}{a^3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where Q is the volume of gas flowing in cubic meters per second, B the width of furnace or flue in meters, h the depth of thickness of gas stream in meters, t the temperature of hot gas in deg. cent., and H a coefficient dependent upon h and B. In this formula the velocity of motion over the "weir" is a function of the expended head and the maximum flow occurs when $h = {}^2/_3\, H$ (Fig. 1).

It was assumed by Yesmann when determining Formula [1] that the maximum flow of an inverted gas stream at constant temperature also occurs when $h = {}^2/_3\, H$, therefore the theoretical quantity of gas Qt flowing per second equals—

$$Qt = \sqrt{\frac{1}{2}\, Bh}\ \sqrt{2\, gh\left(\frac{\Delta i - \Delta m}{\Delta m}\right)} \quad \ldots\ldots\ldots\ldots [2]$$

where Δi is the density of the air surrounding the furnace and Δm the density of the gas in motion.

From this the author proceeds to a brief discussion of Yesmann's hypothesis as expressed by Formula [2] and shows that Formula [1] is correct.

The author discusses next the effect of temperature drop on the flow of gases, a factor which has not been given consideration in the development of the Yesmann formula.

If it is assumed that a gas stream has uniform velocity at every point in its path of travel it is possible to show that the velocity of flow is a function of the temperature drop, and the author claims that practical application of his formula—which is based on this hypothesis—gives results so closely agreeing with actual occurrence as to support the view that temperature drop is a vital factor in gas-stream flow. In the original paper the author gives formulas expressing the flow and involving a coefficient K dependent upon the temperatures T and t. As an example of such a formula may be cited Equation [11] of the original article, namely,

$$Q = 4.42\, B\, \sqrt{H_T{}^3 \times K}$$

where B and H_T (Fig. 2) are expressed in meters, and Q is the theoretical volume of gas at temperature T flowing in cubic meters per second. As K involves the initial and final temperatures T and t, it is essential to know the temperature drop that occurs when the flow of gases through a furnace chamber is computed by means of this formula. It is also necessary to observe carefully the temperature variations that occur in actual furnaces so that when new equipments are to be designed the temperatures T and t can be predetermined with a reasonable degree of accuracy. The coefficient K can then be calculated from a formula given in the original article or determined from curves likewise there given.

The author shows the application of his formula to the computation of the permanence of a producer-gas-fired ingot-heating furnace installed at Swansea and claims that his calculations prove that his formula is much closer to actual conditions than the Yesmann formula.

It should be remembered that the author's formula is based entirely upon the following assumptions: (1) The velocity of the flowing gas stream is uniform at every point in its path of travel; (2) the products of combustion reach the bridge wall of the furnace and pass through the heating chamber at atmospheric pressure; (3) the chimney serves no other purpose than to pull the products of combustion through the outlet ports.

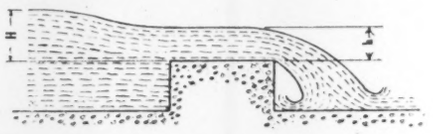

FIG. 1 WATER FLOW OVER BROAD-CRESTED WEIR

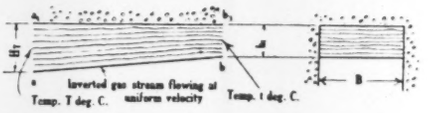

FIG. 2 INVERTED GAS STREAM FLOWING AT UNIFORM VELOCITY

Should the hypothesis upon which the author's formulas are based be correct, the following conclusions will be reached: (1) The velocity of a flowing gas stream is affected by its thickness, and varies proportionately to the $\sqrt{H_T}$; (2) the volume of gas flowing per second, and consequently the fuel consumption, varies proportionately to the $\sqrt{H_T{}^3}$; (3) the velocity of motion and the volume of gas flowing per second are affected by the temperature drop that occurs, and vary proportionately to the

$$\sqrt{\frac{T - t}{\left[\frac{273}{t + 273}\right] \times (T + 273)}}$$

(4) the maximum velocity of a gaseous stream occurs when $t = (0.5T - 136.5)$.

The author hopes to carry out shortly a series of tests on a continuous heating furnace in order to prove or disprove his theory of gas-stream flow, and should it be substantiated the conclusions reached above will be of vital importance to furnish designers and others interested in the problem of industrial heating. The main purpose of the tests will be to determine if the hydrostatic pressures assumed to occur do actually occur in practice, but the experiments cannot be easily conducted due to the difficulty of obtaining instruments that will measure the exceedingly low pressures and at the same time withstand the action of the high temperatures to which they will be subjected. (Herbert Southern in a paper read before the Sheffield Metallurgical Association, Feb. 12, 1924. Abstracted through *The Iron and Coal Trades Review*, vol. 108, no. 2921, Feb. 22, 1924, pp. 298–299, 6 figs., *t*)

HEATING (See Thermodynamics)

HYDRAULICS (See Power Generation and Transmission)

INTERNAL-COMBUSTION ENGINEERING

The Building of the World's Largest Diesel

THIS is a continuation of the article abstracted in MECHANICAL ENGINEERING, February and March, 1924, pp. 95 and 155, respectively, and describes the building of the heads and of the pistons, which involved a long sequence of harrassing troubles.

The final outcome was that the lower head was made of gray iron fitted with ribs which nearly touched the hot face and which forced the cooling water to rush along it with great velocity; the upper head was also made of gray iron but with a double bottom and spiral ribs, provided for the same purpose of increasing the

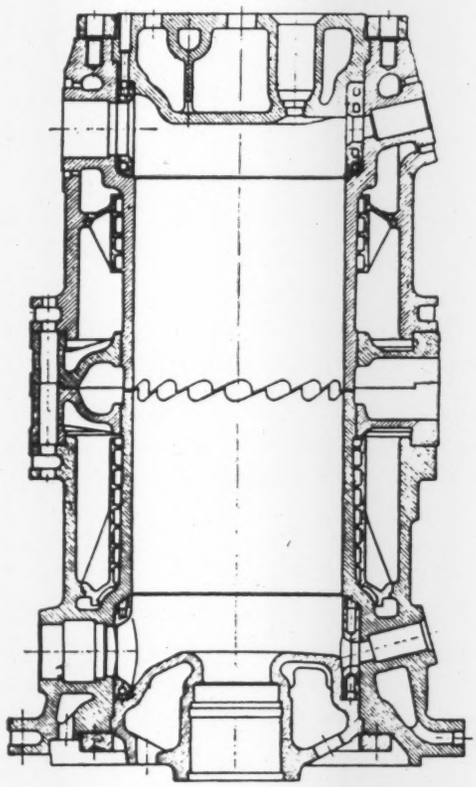

FIG. 3 TEST CYLINDER SHOWING FINAL DEVELOPMENT OF SHIELD RINGS, VALVE CHAMBERS, AND HEAD

heat exchange by forcing the cooling water to move over the surface very rapidly. To maintain a cooling system at high efficiency it is necessary to keep the cooling surfaces free from scale or other deposits, so it was decided to cool the pistons, shield rings, and upper heads with pure distilled water. All other parts are cooled by sea water. The results of these changes may be estimated from the figures of the following tabulation:

	Circulating water gal. per min.	Heat carried away, B.t.u. per hr.
Test No. 1—1830 b.hp.		
Upper head	72.9	361,000
Upper shield ring	77.9	4,570,000
Lower shield ring	32.8	4,570,000
Piston	64.7	9,340,000
Test No. 2—2110 b.hp.		
Upper head	74.7	337,000
Upper shield ring	79.0	4,980,000
Lower shield ring	33.3	5,420,000
Piston	59.4	11,250,000

The overwhelming importance of the shield rings is at once apparent. In both instances the material of the upper ring was gray iron, that of the lower one being cast steel.

The trials with this cylinder were concluded by a continuous run of 5 days, the load being 2120 b.hp. and the speed 127 r.p.m. An inspection after the test showed that the new lower part was free from cracks and that in the upper part new cracks had not developed.

But again a new trouble had made its appearance. Corrosions were found on that part of the cylinder wall covered by the shield ring and also on the back of the ring itself. The reason for them was traced to the fuel oil, which originally was standard Diesel oil but was later charged to tar oil. The fuel valves had been designed to use tar oil and the engine had been run for quite a while, and especially during the five-day trial, on this fuel which contains an appreciable amount of sulphur. The sulphurous and, eventually, sulphuric acids which are formed during and after the combustion of this element condensed on the cold walls of cooling ring and cylinder either during the operation of the engine or after stopping it, and corroded their faces. There is also a chance that galvanic actions may have taken place. These corrosions were easily overcome by spraying the walls with tin and lead with the well-known Schoop sprayer.

After the successful termination of this series of experiments a new upper part was built on the lines of the lower one and the two parts together subjected to a run of 500 hr. at 2100 b.hp. An examination of the cylinder parts which now had run between 513 and 1345 hr. showed them to be in splendid condition. In order to play safe, an entirely new cylinder was now built which corresponded exactly to the last one, and this with the original parts of the rest of the engine was subjected to a trial of 503 hr. duration at full load. This was done in order to determine whether the ability to stand up was intrinsically inherent in the design. The inspection after the trial showed very satisfactory results. Some of the parts had already stood up during 1590 to 2575 hr. of operation. Thus was proved to the satisfaction of the builders that the problem of the double-acting 2000-b.hp. two-cycle cylinder had finally been solved.

Data are presented also regarding trials with the experimental cylinder. (F. Englert in *Motorship*, vol. 9, no. 2, Feb., 1924, p. 119, 1 fig., *dh*)

A Cold-Starting Oil Engine

DESCRIPTION of a new type of vertical oil engine built by Ruston & Hornsby, Ltd., Lincoln, England. These engines are of the 4-cycle, solid-injection, high-compression type. The compression pressure is sufficiently high to raise the temperature of the contents of the cylinder up to the ignition point but it is impossible to get any preignition as the delivery of the fuel charge into the cylinder head is very exactly controlled by the cam-operated pump and the position of the cams in relation to the crankpins is rigidly fixed once the preliminary adjustments have been made.

Two types of these engines are built. One type has open frames, while the other is totally enclosed. The open type has light sheet-metal covers to close in the openings between the legs of the standards.

The inlet and exhaust valves are arranged horizontally on opposite sides of the cylinder heads, and although some engineers seem to have an objection to horizontal valves, the makers claim that they have never experienced any more difficulties with them than they have with vertical valves. The valves are operated by separate eccentrics on the layshaft, through rods and bell cranks. On the shaft of the bell crank, which is journaled in the valve head, there is a curved lever that bears against the head of the valve stem and forces the valve open against a spring. The curvature of this lever is such that the valve is let down quite gently on to its seating, but is nevertheless opened rapidly. The result is very quiet running, so that conversation can be carried on on the platform round the cylinders. The valves are all of the mushroom type, and the gear, with the exception of the eccentrics, is enclosed in oiltight casings. The eccentric rods for the air inlet valves, which are at the back of the engine, would be unduly long if made in one piece and might vibrate when running at full speed. They are consequently made in two lengths, and each half is pivoted to a small rocking arm which can be seen just above the level of the platform. The rocking arm does no work and merely acts as a steadying device. It will be noticed that there is a small auxiliary bell crank and linkwork on each of the exhaust-valve heads, which are in the front of the engine. This gear is only used for releasing the compression pressure when it is desired to bar the engine round.

The fuel pumps, one for each cylinder, are all grouped together

at one end of the engine, and are driven directly off the layshaft. The general arrangement of the oil pumps is illustrated by Fig. 4, from which it will be seen that the plungers are operated by cams through rocking levers. There is no backlash in the driving gear, which is naturally conducive to silent running, and the injection is timed, on the test bed, by shaping a separate piece screwed into the highest part of the cam. There is thus no chance of the timing becoming deranged during service, but it can be altered, if necessary, to accommodate a change in the oil, fuel for instance, by replacing the shaped piece in the cam.

The quantity of fuel sucked by each pump remains constant at all loads on the engine, but the amount delivered to the cylinders is varied by bypassing so much as is not required to meet the demand on the engine. The bypass ball valve can be seen on the left of the left-hand view in the enlarged drawing, Fig. 4, and is opened when the little floating lever below is raised by the governor

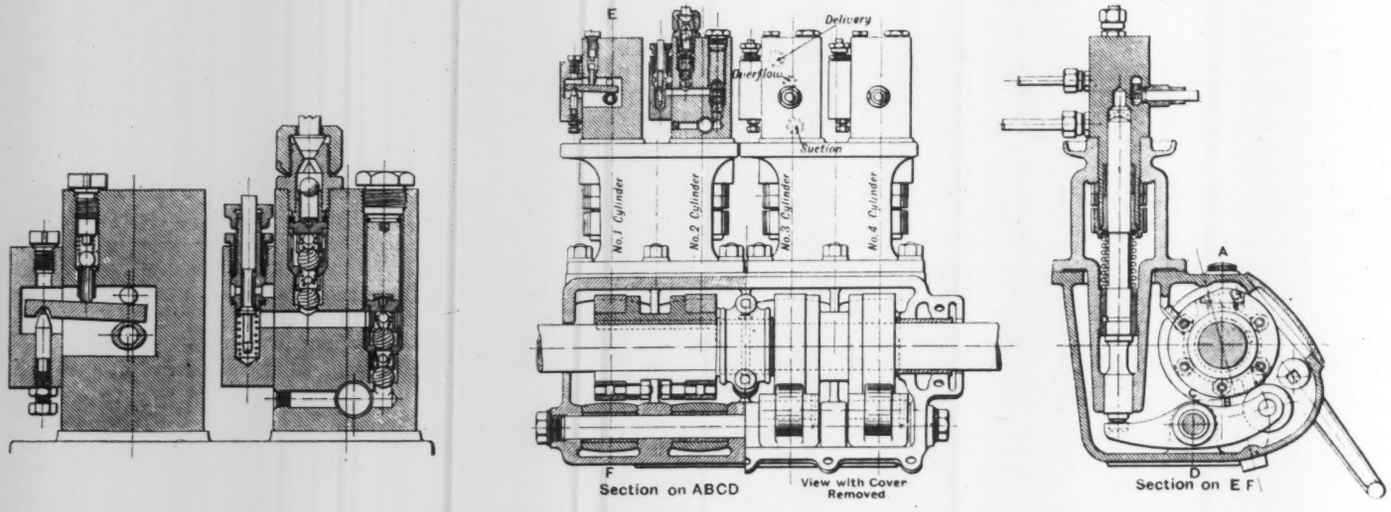

FIG. 4 OIL-FUEL INJECTION PUMP AND BYPASS BALL VALVE OF THE RUSTON-HORNSBY COLD-STARTING OIL ENGINE
(Pump at right, bypass ball valve at left.)

turning the cam under its right-hand end. Some of the oil then overflows back to the fuel tank. The extent of opening can be adjusted for each pump by means of the set-screw abutment of the lever. The pump cylinders are machined out of solid steel forgings, and are very nice pieces of workmanship. Both of the inlet and delivery valves are of the ball type, having two balls in tandem. (*The Engineer*, vol. 137, no. 3555, Feb. 15, 1924, pp. 180–181, 5 figs., *d*)

Airplane-Engine Designing for Reliability

A PAPER based largely on the experience of the Wright Aeronautical Corporation. The author points out that as a result of work accomplished in the last few years two types of eight-cylinder V-type water-cooled engines and one twelve-cylinder V-type, all weighing less than $2^1/_2$ lb. per hp., have run for periods of from 200 to 300 hr. with but little attention, and one six-cylinder dirigible-type engine weighing $3^1/_4$ lb. per hp. has been operated for 300 hr. without disassembling. Wartime engines had the most trouble with exhaust valves, connecting rods, big-end bearings, and ignition.

The first of these difficulties was solved after an extended test problem by a compromise tulip-shaped valve of silchrome steel working in an aluminum bronze seat. The connecting-rod design originally used consisted of a steel forked rod bearing on the babbitt-coated shell of the blade rod, which in turn was babbitt lined and bore on the crankpin. This was replaced by a connecting rod of the so-called marine type in which the forked rod carries a babbitt-lined bronze box bearing on the crankpin and the blade rod bears on it. The principal difficulty experienced with this construction was due to the flexing of the bronze shell, which in turn disintegrated the babbitt lining. The bronze bearing was then changed to a steel bearing and the babbitt was removed entirely. These bearings were run 572 hours at full power without adjustment and no appreciable wear could be measured at the end of this time.

The ignition difficulty was solved by better workmanship and better design of magnetos. These have been generally used on the recent 12-cylinder engines and it is not unusual to find magnetos running from 3000 to 3600 r.p.m. This high speed has caused considerable trouble, but satisfactory equipment is now available. The situation with spark plugs is still not entirely satisfactory.

As regards future design the author develops many points, of which only a few may be mentioned. He claims that the simplest design is always the best. It is of the utmost importance to have correct distribution of proper material in each piece, and large bearing surfaces should be provided. Rigidity must be considered in every piece and in the assembly as a whole. With higher speeds of operation it is absolutely necessary to have rigid crankshafts and crankcases. Either reasonable factors of safety must be used or very fine material, and the factors of safety in each part should not be based on the best material or on the most perfectly made part, but rather on the average material that will be used in production, allowance being made also for slight inaccuracies in machining. The use of the elastic limit rather than the tensile strength as a basis of calculation is recommended, and proper consideration should be given to the fatigue of materials.

Aside from fatigue, probably the greatest number of failures occur because enough consideration has not been given to the operating conditions of the power plant.

The methods used in developing a design at the Wright Company are described. The conclusion to which the author comes is that reliability in light-weight aircraft engines is secured by the correct distribution of proper material and the adequate provision for the lubrication of the moving parts at all times. Each entirely new design becomes heavier as a result of duration testing, but by development through successive models the weight per horsepower can gradually be reduced to the minimum for an engine of given duration capacity. A thoroughly reliable power plant is the result of a long and expensive process of evolution, both of design and of manufacturing methods. Production engines of proved design may be entirely unsatisfactory in service if sufficient care has not been taken to see that the requirements of the design are complied with. The engineering department must therefore not only follow through the quality of the production work, but also the troubles of the service department, if the product is ultimately to be successful. (Geo. J. Mead in *The Journal of the Society of Automotive Engineers*, vol. 14, no. 3, March, 1924, pp. 277–285, 13 figs., *g*)

New Methods of Energy Generation—Stauber Gas Turbine

THE author discusses the various new paths sought and partly opened up in the domain of power generation. It would appear

that, notwithstanding the great advance made in this field, there are still many industries where the waste of power is tremendous. The chemical industry is cited as a shocking example in this respect.

One of the directions in which a better utilization of energy is sought is that of increasing the speed of prime movers and driven machinery. The advantages of high-speed operation are particularly evident in the case of pumps and compressors where high speed makes it possible to reduce materially the size and hence cost of installation and also to attain more economical operation. The development of multi-stage high-speed pump rotors and of the efficient transformation kinetic energy into pressure by means of diffusers and the like has made the high-speed pump available for a wide range of application. It is not so long ago that, for example, reciprocating compressors of gigantic dimensions were used in mines. Today they have been replaced by small powerful and efficient turbo-compressors, and the same applies

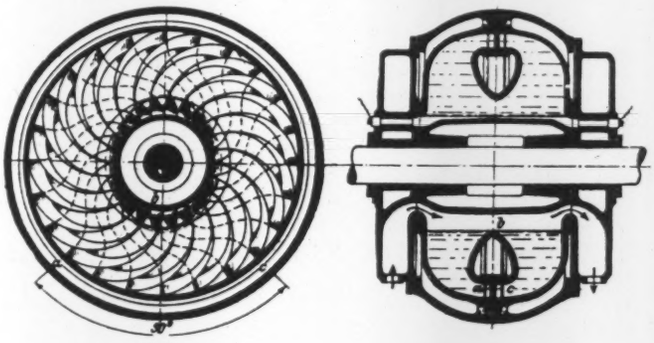

FIG. 5 STAUBER GAS AND OIL TURBINE

not only to the large sizes but to the medium and small sizes as well. The original article contains an illustration of a Brown-Boveri & Co. compressor in which one small wheel runs at 20,000 r.p.m. and a peripheral speed of 250 meters (820 ft.) per second, delivering air at a pressure of 0.5 atmos. It would be necessary to have only a few such rotors in series to deliver air at the pressure of 7 to 10 atmos. used in mining. Such a compressor electrically driven through a speed-change gear occupies only a fraction of the space needed by a reciprocating compressor of the same output, and this means that the cost of its installation underground is correspondingly smaller, and yet such a simple turbo-compressor has an isothermal efficiency of 60 per cent, or about as good as a reciprocating compressor of the same output.

From the point of view of thermal efficiency the Diesel engine with its 35 per cent or so factor stands at the top of the list, but even here a considerable improvement could be obtained were it possible to increase its speed to any material extent. At the last automobile show in Berlin in the fall of 1923 there was exhibited by the Daimler Motor Co. a passenger bus converted from a truck. This bus was driven by a four-cylinder 40-hp. air-injection Diesel motor normally running at 800 to 1000 r.p.m. It was stated at the time that this motor ran without trouble on the testing stand at speeds up to 1600 r.p.m., but the author has not been able to establish how this motor would operate at these higher speeds for any length of time in actual practice. The remarkable part about it is that this little Diesel engine ran with compressed-air injection and that notwithstanding the high speed the injection compressor operated very well.

One of the most interesting developments still under way in the power plant field is the gas and oil turbine, of which the Holzwarth is one of the best known. Here the experimenter has to overcome the extremely unfavorable conditions affecting the materials of construction of the turbine. That these conditions can be overcome is indicated by reports regarding the Stauber turbine (Fig. 5), as it is stated that such common materials as cast iron and steel have been successfully used in its construction. In a structure consisting of at least one pair of bucket wheels with intervening stationary blades for transforming pressure energy into velocity energy is whirled a mass of water, which, after it reaches a state of equilibrium with only centrifugal force acting on it, forms a closed ring of water. Combustion impulses, introduced from the inside of this ring of water, chiefly at symmetrically opposite points, impart to the ring a relative motion which causes in it an elliptic deformation and thereby a flow from one rotating wheel to another, and also the transformation of the pressure energy set up as a result of combustion into energy of flow; this in its turn imparts a torsional moment to the axle of the rotating wheel similar to what happens in a water turbine. In Fig. 5 the course of flow from the first rotating wheel to the stationary blading and from there back to the rotating wheel is indicated by the letters *a*, *c*, and *d*. The first turbine of this design is now being experimentally operated by the German General Electric Co. in Berlin. It runs at the low speed usual for water turbines and is limited to smaller outputs than steam turbines.

The construction of the Stauber turbine involved a number of new and startling problems, the solution of which made great demands on the skill and inventive ability of the designers. The fundamental idea combines in a fortunate manner the generation of energy by combustion inside of the turbine with the necessary wheel and bucket cooling, and thus avoids the great difficulties hitherto encountered in dry gas turbines.

The author points out in this connection that while the gas turbine has the advantage as compared with the steam turbine of eliminating the boiler, recent developments in steam-turbine design together with the use of high-pressure steam have been so promising as to decrease materially the commercial possibilities of the gas turbine, at least in the near future.

In the past far more attention has been paid to the low-pressure end of the turbine, where the pressures ranging from 1 atmos. down to condenser pressure are handled. The development of the high-pressure end had been more or less neglected. This is no longer the case, and recently turbines have been developed for operation for very high pressures. The author mentions the Lösel turbine of the Erste Brünner Machine Co., which has already been described elsewhere, and the work of the Brown-Boveri Company, which concern proposes to use steam at 100 atmos. pressure. This has also been described in MECHANICAL ENGINEERING, vol. 47, no. 1, Jan., 1924, p. 40. (Dr. Löffler, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, no. 8, Feb. 23, 1924, pp. 161–169, 18 figs., *dgA*)

MACHINE PARTS AND DESIGN (See also Testing and Measurements)

Super-Accuracy in Gear Ratios

AN INVESTIGATION undertaken with the object of devising if possible a simple method for securing a high accuracy in the design of gearing having the desired ratio, rather than to discover a correct method of solving the problem. In order to make the scheme as comprehensive as possible it was decided to permit the use of change gears from 14 to 199 teeth in single and double trains only.

The authors point out that to facilitate the calculations it is advisable, though not absolutely necessary, to have a ratio table for all numbers from 1 to 199. This has been worked out but is too voluminous to print in full.

The authors begin with repeating decimals and show how they can be handled. A few examples of recurring decimals are given together with the method of working them out. Examples are also given showing the result of adding or subtracting the fractional ratios or decreasing ratios to or from the fractional elements of their required ratio. The authors give two methods for working out *all* ratios from three places of decimals and upward, whether repeating or not. The two methods and an example for the application of one of them are as follows:

Method 1. To get quickly a close approach to the required ratio, correct to as many places of decimals as given in the required ratio. This plan is applicable to all ratios up to six places of decimals, in many cases up to eight places of decimals, and in some cases up to any number of places of decimals.

Method 2. The degree of accuracy required may be the principal feature, and should it be necessary to have the nearest possible ratio obtainable to the required ratio, we should have to exhaust that ratio; i.e., try every possible combination to get the best solution obtainable by double trains. This of course is a long and tedious operation, but can be shortened, as will be shown further on.

Example—Ratios of Three Places of Decimals, Method 1. Ratio required, 0.223. This figure, being a prime number, will not factorize, so we find the nearest ratio to it, which is 29/130 = 0.22307.

Next place the numerator and denominator of required ratio in two columns. Now add the approximate-ratio numerator and denominator to these as shown.

223	1000
29	130
252	1130

As these two numbers are both factorizable, the ratio 252/1130 is worked out thus:

$$\text{Change wheels} = \frac{14 \times 18}{10 \times 113} = \frac{14}{50} \times \frac{90}{113} = 0.223008$$

This ratio will be considered as near enough to meet the requirements. It generally happens that this adding together has to be repeated several times before one gets either numbers that factorize or that give a result near enough to that required. As an alternative, these numbers, as already explained, can also be subtracted, which gives similar results, and examples of these will be given further on.

The authors give the following in connection with the subject of exhausting the ratio and show a method (not abstracted here) for reducing the time taken by this problem.

It is well known that by adding a given ratio to itself for a certain number of times it will eventually give an answer equal to the fractional equivalent of that ratio.

Take ratio 0.571428 and adding thus:

1	0.57142857
2	1.14285714
3	1.71428571
4	2.28571428
5	2.85714285
6	3.42857142
7	3.99999999

Here it is found that after adding the ratio to itself for six times an answer is obtained equal to 4; this gives the equivalent fraction $^4/_7$, which gives the ratio 0.571428.

This answer always works out with a certain number of ciphers or figures 9 following the decimal point, and naturally the oftener these figures follow one another the nearer the required ratio is approved. However, no one can afford the time to keep adding a ratio to itself in this manner, as in an extreme case this operation would have to be repeated 39,601 times.

The other problems discussed in the original paper are those of increasing or decreasing ratios and finding the mean ratio between two given ratios. This latter is as follows: Change wheels might be required for a ratio exactly half-way between two others. For instance, take the two ratios 51/113 = 0.4513274336 and 41/79 = 0.5189873417. The mean of these is 0.4851573876. A simple way of doing this is to bring the two denominators to the same figure by cross-multiplying thus:

$$51 \times 79 \text{ and } 113 \times 79 = 4029 \text{ and } 8927$$

$$41 \times 113 \text{ and } 79 \times 113 = 4633 \text{ and } 8927$$

The mean of 4029 and 4633 is 4331, giving the fraction 4331/8927, which gives the required ratio, and it is found these numbers factorize thus: 61/79 × 71/113, which gives the change wheels required. If these numbers do not factorize it would be necessary to approximate to them, as explained previously. (T. M. Lowthian and W. Owen in *The Engineer*, vol. 137, no. 355, Feb. 15, 1924, pp. 164–166, *pA*)

Rubber Replacing Lignum Vitae and Babbitt Metal for Stern Bearings

ONE of the first rubber stern bearings was installed in the summer of 1922 to replace the usual babbitted bearing on a Diesel power tug. This bearing was designed by David W. Dickie for the State Harbor Commissioners of California. It has given satisfaction and when examined after ten months of service showed no signs of wear on either the bearing or the shaft. Numerous other installations have been made both in the marine field and in the pump field. Such firms as the Worthington Pump and Machine Co., Chicago Pump Co., and others are said to have adopted them as standard equipment on their pumps. Rubber bearings have carried loads as high as 375 lb. per sq. in. of projected bearing surface, and a wetted rubber surface has a lower coefficient of friction than an oiled babbitt surface. It is said also to have been demonstrated that no amount of grit or sand will either cut the bearing or score the shaft that operates in the bearing. This is due to the fact that it is impossible to embed a piece of sand or grit in the soft-rubber surface of the bearing. Consequently the sand or grit is rolled to a deep spiral groove in the rubber of the shaft and is washed out by the water which also circulates through the grooves. Rubber bearings need water for their lubrication.

The spiral groove runs then the entire length of the bearing and provides a channel for the lubricant and also carries out any sand or grit which may come into the bearing. It is claimed to have been actually demonstrated that the rubber bearing material reduced screw vibration, cushioning any inequalities of pitch and not transmitting through the whole craft the entire vibration. Rubber bearings in service are operating on speeds as high as 5000 r.p.m. and as low as one revolution in three minutes. It is further said that a rubber bearing permits a shaft that is misaligned to operate without pound or noise. When operating on a misaligned shaft the rubber bearing acts as a shock absorber and prevents undue vibration being transmitted through the shaft. (*Motorship*, vol. 9, no. 2, Feb., 1924, pp. 110–111, 1 fig., *d*)

MACHINE TOOLS

Sommer & Adams Rotary Spline-Hobbing Machine

IN THIS machine, which was designed primarily for hobbing splines on one end of automobile-axle shafts, eight pieces of work are finished by as many hobs, while practically the entire machine with the exception of the base revolves past the operator. On the basis of one revolution of the machine every 4 min. a production amounting to 1080 pieces per 9-hr. day, or one piece every 30 sec., can be obtained. It is said that the machine can easily be run at a faster rate of speed with increased production.

In the machine there are eight distinct units spaced equidistantly around the machine. Each unit consists of a work head, a cutter head, and mechanism for driving both.

The original article describes in detail the construction and operation of the machine. Attention may be called in this connection to the fact that one such machine is able to supply with axles about 150,000 automobiles in one year, which is more than any country outside of the United States produces, with possibly one exception. (*Machinery*, vol. 30, no. 7, March, 1924, pp. 555–556, 3 figs., *d*)

MARINE ENGINEERING (See Machine Parts and Design)

MECHANICS

The Stresses in a Uniformly Rotating Flywheel

THE determination of the stresses set up in a uniformly rotating flywheel is a problem which is treated in most textbooks upon the assumption that the arms are not connected to the rim. This assumption renders the problem a simple one, since, under the action of centrifugal force, the rim is supposed to be subjected only to a pure hoop stress and the arms to a tension varying from a maximum at the nave to zero at the rim; no bending action is allowed for on any part of the rim. The hoop stress in the rim produces a corresponding increase in its length, and so the radius of the wheel is increased: similarly the tensile stress in an arm produces an increase in its length. If the increase in the length of an arm and in the radius were equal, no extra stresses would be

set up in the wheel by connecting the rim to the arm. Such, however, is not the case; the increase in wheel radius is greater than the increase in arm length, and there is thus a tendency for them to separate. When there is a good connection between the arm and rim, as in practice there must be, this tendency is counteracted partly by an extra stretch in the arm and partly by a bending inward of the rim at the point of attachment of the arm.

Several attempts have been made to provide a solution of the complete problem. The usual method of attack is to obtain the differential equation to the elastic line of the rim and to work from this. In some instances the equation is incorrectly stated and in others somewhat unjustifiable assumptions are made: in any case the method is a laborous one.

In the present paper a different method of analysis founded on certain theorems of Castigliano is used, which leads to formulas of a straightforward and easily applied type. An essential investigation dealing with the stresses in a ring subjected to a system of radially applied forces is given as an appendix.

The theorem of Castigliano which is referred to above states that if any member of a redundant framework is initially of incorrect length and forced into position, the first differential coefficient of the strain energy of the structure with respect to the force in the redundant member is equal to the initial lack of fit.

The author determines the complete differential coefficient which gives the amount by which the arm was initially too short to meet the rim, i.e., the amount of separation during steady rotation of the flywheel, assuming there is no connection between the arms and the rim. From this he proceeds to the determination of the separation of the rim from the arm if independent straining occurs. He determines this first without taking into consideration the effects due to rotation, which latter are discussed next. Adding the centrifugal effects to the results previously obtained he obtains formulas for the tension in arm at junction with rim; the tension in rim at arm section; tension in rim at mid-section; bending moment at arm section; and bending moment at mid-section.

In appendices are discussed and calculated the bending moments and forces on a ring subjected to a series of equal and equally spaced radial pulls, and the author compares his work with that of Prof. John Longbottom, published in Transactions of the Institution of Engineers and Shipbuilders of Scotland, vol. 42, no. 4, 1919, showing that the agreement between the results obtained is quite good. Professor Longbottom employed in his calculations the principle of least work.

A long communication from Professor Longbottom criticizing the present paper is appended. (Prof. A. J. Sutton Pippard, University College of South Wales and Monmouthshire, in *Proceedings of the Institution of Mechanical Engineers*, no. 1, 1924, pp. 25–42 and discussion pp. 43–51, 6 figs. in original paper and 1 in discussion, *t*)

MOTOR-CAR ENGINEERING

The Weiss Continuously Variable Transmission

THIS transmission consists of driving member in the form of a substantially hemispherical shell (Fig. 6). Within this shell there is a body known as a "mutor," which is of ring, wheel, or disk form and is adapted to rotate around its axis on a handy friction bearing. The axis of this mutor intersects the axis of the shaft of the driving member at the center of the hemisphere, but the angle between the two axes can be varied by suitable mechanism.

The mutor carries on its circumference a series of ball bearings which are mounted on studs projecting a short distance from each side of the inner race of the bearing. Each projection of the stud rests on a spool-shaped roller, the ends of the spools being supported on cam-shaped surfaces formed on the mutor, as illustrated in the detail view.

Referring again to the general view, it will be seen that as the driving shaft revolves, the point where the ball bearing contacts on the hemispherical shell describes a circle around the axis of the driving shaft. When the axis of the mutor is at right angles to the axis of the driving shaft the diameter of this circle is zero, but as the mutor is swung around from this position it increases until it attains a maximum value when the mutor axis coincides with the driving-shaft axis. In practice, owing to interference of parts, this latter position is not always attainable.

Firm driving contact between the hemispherical shell and the outer race of the ball bearing is established by the ball bearing being slid in the direction of its axis on the rollers in the mutor, which results in a wedging action similar to that taking place in a ball or roller ratchet. In some respects the conditions of the drive

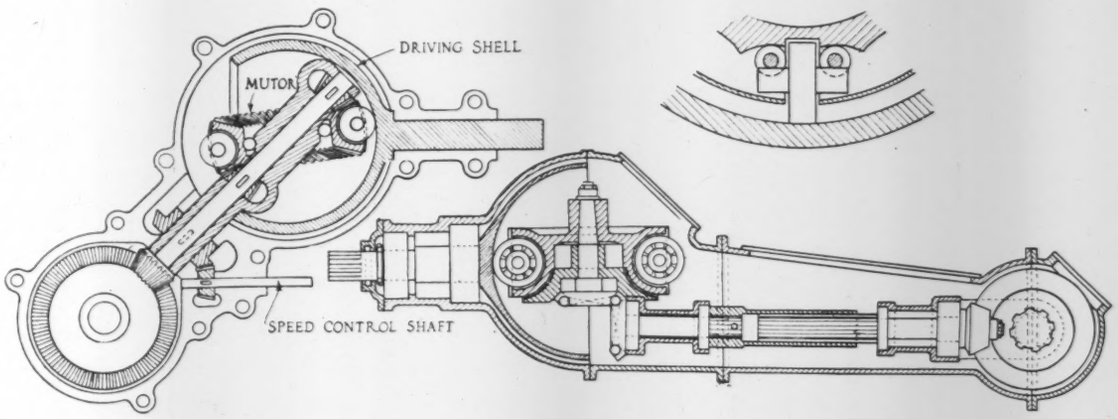

FIG. 6 TWO FORMS OF THE WEISS CONTINUOUSLY VARIABLE TRANSMISSION, WITH DETAIL VIEW OF ANNULAR BALL BEARING ON ROLLER MOUNTING

are not unlike those in a friction-disk-and-wheel combination, with which a continuous variation of the transmission ratio is also obtainable. Differences, however, arise because in this case the contact is metal-to-metal, because there are as many lines (or surfaces) of contact as there are ball bearings instead of a single one, and because the transmission ratio can be varied without interrupting the drive.

In any intermediate position of the relative to the driving shell the motion imparts to a point in the circumference in the ball bearing will be partly rotation around the axis of the ball bearing and partly rotation around the axis of the mutor. With the inclination of the mutor axis to the driving-shaft axis the rotation of the mutor around its axis per revolution of the driving shaft changes and the ratio of transmission changes. (*Automotive Industries*, vol. 50, no. 12, Mar. 20, 1924, pp. 674–675, 2 figs., *d*)

POWER GENERATION AND TRANSMISSION

Wave Transmission of Power

DATA of tests carried out in 1917 at the Air Ministry Laboratory to determine the efficiency of the hydraulic system of power transmission developed by Constantinesco and used during the war in synchronizing devices for machine guns on airplanes and applied since to small tools such as rock drills, riveters, etc.

The paper gives the elementary theory of the apparatus and efficiency calculations which are followed by data of actual efficiency tests. The figures given for the hydraulic efficiencies are subject to a small reduction in order to allow for the different efficiencies of the electric motor. Hence the maximum hydraulic efficiency of the two systems tested cannot be greater than 80 per cent. It should once more be pointed out that this is for a system of small bulk and high pressures. With smaller pressures there would be higher velocities required for the same power, and smaller efficiency. With greater dimensions and the same

pressures, there would be less velocities required and greater efficiency obtained. (H. Moss, Director of Science, Imperial College of Science and Technology, in a paper presented at a meeting of the Institution of Mechanical Engineers and published in *The Proceedings of the Institution of Mechanical Engineers*, No. 1, 1924, pp. 1–24, 6 figs., *e*)

POWER-PLANT ENGINEERING

The Benson Boiler

THE Benson boiler was described in America in *Power*, May 22 and 29, 1923. The remarkable feature about it is that it supplies steam at a pressure of 3200 lb. per sq. in. and at approximately 720 deg. fahr. temperature.

It is stated that one unit designed for supplying a turbine of 250 kw. capacity has undergone successful trials in Rugby, England. It is further stated that there has been no difficulty in generating steam continuously at 3200 lb. pressure without the absorption of latent heat at about 720 deg. fahr. (with a very slight superheater), reducing it to 1500 lb. pressure, and superheating it even as high as 910 deg. fahr. Very satisfactory quantitive tests have been carried out showing a high generation efficiency. (*Iron and Coal Trades Review*, vol. 108, no. 2922, Feb. 29, 1924, p. 349, *gA*)

New Softening Agent for Water Treatment

THE new material, called "doucil," is of the base-exchange type and belongs to the same major class as permutit.

The oldest base-exchanging compounds on the market, the natural zeolites, consist of rounded granules of no great degree of porosity and it is evident that all the softening action takes place very close to the external bounding surface of the grain. Chemical analysis shows that but a little proportion of the soda content of a natural zeolite is available in water softening.

Tests and observations indicated that if suitable porosity and surface porosity and surface could be secured it should be feasible to produce a base-exchanging compound in which much more of the combined soda could be utilized to produce soft water than in previous materials, natural and artificial. This expectation is said to have been realized when it was discovered how to produce a complete silicate containing replaceable combined soda in the form of a dried gel.

The final dried and washed product conforms closely to the anhydrous composition Na_2O, Al_2O_3, $(SiO_2)_5$, which demands 13.3 per cent Na_2O, 22.0 per cent Al_2O_3, and 64.7 per cent SiO_2. Of the soda present, rather more than 3 per cent is converted into non-exchangeable calcium silicate, and the remaining 10 per cent can be completely replaced alternately by lime and by soda.

For practical purposes, however, and especially if completely softened water is required, about 40 per cent of the exchangeable soda, or 4 per cent of the weight of anhydrous doucil present, is exchangeable for lime before the doucil allows appreciable quantities of calcium or magnesium salts to escape.

At first the manufacturers were unduly afraid of the resistance of water flow, and recommended the use of relatively large grains, at least in the lower part of the doucil bed. It was soon found, however, that softening capacity was being wasted in this way, and that the material was sufficiently hard not to pack down too tightly under water pressure when used in a smaller grade.

The preferred size is now from $^1/_8$ to $^1/_{20}$ in., while a still smaller size, $^1/_{20}$ to $^1/_{30}$ in., is sufficiently granular to be very useful as a top layer in a doucil filter. A bed 6 ft. deep of the former size offers a resistance to water-flow of only about 1 lb. per sq. in. at normal rates of flow, while a 3-ft. bed of the smaller grade has a resistance of about 4 lb. per sq. in. under similar conditions.

The salt consumption is much reduced by using the last portion of the brine from one regeneration as the first half of the brine for the next regeneration. The simplest way to operate a doucil plant is to pass the hard water downward; regeneration should take place in the direction of upward flow. It is important to preserve the surface of the doucil grains in an absolutely clean condition, and therefore only water free from suspended matter should be admitted to the doucil bed. (Paper by T. P. Hilditch and H. J. Wheaton, presented before a conference on the Treatment of Water for Industrial Purposes, held jointly by the Institution of Mechanical Engineers and the Chemical Engineering Group of the Society of Chemical Industry in London, Feb. 26, 1924. Abstracted through *The Chemical Age*, vol. 10, no. 246, Mar. 1, 1924, pp. 215–216, *d*)

PUMPS (See Machine Parts and Design)

RAILROAD ENGINEERING

Lehigh Valley 3-Cylinder-Locomotive Tests

DESCRIPTION of a 4–8–2 three-cylinder mountain-type locomotive built by the American Locomotive Co. for the purpose of determining the advantages and disadvantages of this type of plant.

The advantages claimed for the three-cylinder locomotive are its more uniform torque, the lower factor of adhesion which this makes practicable, and the improvement in combustion conditions resulting from the more frequent and softer exhaust impulses.

This locomotive was built primarily to determine the characteristics of the three-cylinder feature and in other respects it is built along standard lines. It would appear that one of the reasons for this is the elimination of as many variables as possible with the exception of one, the effect of which it is the purpose to measure. Probably it is for this reason that such features as a feedwater heater and booster have not been incorporated into the design of this locomotive.

The Lehigh Valley locomotive, which is a completely new design, has the same size of cylinders and driving wheels as the converted New York Central locomotive. The boiler, however, is built with a combustion chamber and fitted with a Type A instead of a Type E superheater. Unlike the New York Central locomotive, the main rod of the inside cylinder is connected to the second pair of driving wheels, while the outside main rods are coupled to the third pair of wheels.

Road tests of this locomotive produced highly satisfactory results. In particular it was found that the average cut-off at which the locomotive worked was 53 per cent and the fuel consumption on one run was 2.56 lb. per i.hp., in which is included the coal required to operate the stoker and air pumps as well as that lost at the pops.

No record of the drawbar pull of the locomotive and its exact performance when starting was made, but it was generally observed that the train started smoothly and quickly and with a noticeable absence of jerks. Its riding qualities are said to be exceptionally smooth and free from lurching and vibration at high speed. It has also proved itself capable of performing well on grades. In some cases it has handled trains as heavy as 1550 tons and has been capable of maintaining schedules on the division to which it has been assigned which require speeds of over 60 m.p.h. to be maintained frequently on their level portion. (*Railway Age*, vol. 76, no. 15, Mar. 15, 1924, pp. 755–757, illustrated, and editorial entitled One Experiment at a Time, on p. 726, *dg*)

Southern Pacific 4-8-2-Type Locomotives

THESE locomotives were designed to haul trains of twelve passenger cars on 2 per cent grades through difficult mountain and desert territory a distance of 815 miles, which is done without changing locomotives. This establishes a new record for long locomotive runs.

The outstanding characteristics sought in this design were maximum tractive power within the weight limit and ample boiler capacity for the long sustained runs. This required refinement in design to provide ample strength with minimum of weight, necessitating the use of materials of high tensile strength for many parts.

Only certain features can be reported here. The journal bearings throughout are unusually large, especially the main, which is 13 in. in diameter by 22 in. long. The spring rigging has been constructed to incorporate bent equalizers. This design of equalizers provides a more stable construction by keeping the spring rigging

lined up. On lighter power this is not essential, but on the larger locomotives it is expected to obviate the trouble ordinarily experienced with the spring rigging.

One of the outstanding features in the design of this locomotive is what has been accomplished in obtaining increased tractive force without increasing the stresses set up in the track and roadbed. To accomplish this, the engine is equipped with a constant-resistance centering device. Also, the forward pair of drivers is fitted with the Franklin lateral-motion device, thus making ample provision for the engines to take curves with a minimum stress in the track. These centering devices also hold the engine steady on a tangent track, reducing to a minimum the lateral movement due to the steam action.

In order to keep down the dynamic augment to a minimum, the engine is equipped with connecting rods of normalized carbon-vanadium steel of I-section, hollow piston rods, and Z-type pistons, thus providing light reciprocating parts, 50 per cent of which are balanced. The total weight of the reciprocating parts is 1830 lb. or one pound to each 201 lb. of the total weight of the locomotive in working order as compared with the ratio of 1 to 160, which is generally considered good practice.

A tabulation in the original article shows a comparison of the weights of the reciprocating and revolving parts for the 4–8–2-type locomotives with the weights of similar parts for the 2–8–2 and 4–6–0 types which the new locomotives displace. From this tabulation it appears that by refinement in design and the use of higher-grade material a much more powerful and heavier locomotive has been built without increasing the disturbing forces in track.

The original article gives also the specifications for the special materials used in parts subjected to heavy stresses and a list of parts made of each of the materials. (*Railway Mechanical Engineer*, vol. 98, no. 3, March, 1924, pp. 141–146, 13 figs., *d*)

STEAM ENGINEERING (See Power-Plant Engineering)

TESTING AND MEASUREMENTS (See also Thermodyamics)

Equalizer Apparatus for Transverse Tests of Bricks

THE American Society for Testing Materials has described the apparatus to be used for making transverse tests of building bricks. As this apparatus is made up of many loose parts, failure of the specimen throws them out of position, and considerable time is consequently required to prepare the next specimen for test.

A new equalizer apparatus has been designed, built, and tested which gives practically the same values for the modulus of rupture as the A.S.T.M. apparatus. It consists of two equal-arm levers about the length of the brick, mounted side by side on a pin at the middle of their length. At each end the levers have barrel-shaped knife edges carried on vertical spring-steel plates, which allow longitudinal movement of the knife edges. The levers equalize the four forces acting upward on the lower surface of the brick. The upper knife edge and the bearing plate are adjustable.

In making the comparative tests the testing-machine operator tried to work as rapidly as was consistent with obtaining reliable readings. The time required to test 50 cement bricks in each lot, using the A.S.T.M. apparatus, was 2 hr. 30 min. flatwise, and 2 hr. 45 min. edgewise. The corresponding times, using the equalizer, were 1 hr. 27 min. and 1 hr. and 35 min. Forty-two per cent of the testing time was therefore saved by using the equalizer apparatus.

Comparative tests showed that for clay, cement, and sand-lime bricks the modulus of rupture obtained with the equalizer apparatus was practically the same as that found with apparatus made in accordance with the recommendations of the American Society for Testing Materials. (H. L. Whittemore, Mem. A.S.M.E., in *Technologic Paper of the Bureau of Standards*, vol. 18, no. 251, Feb. 5, 1924, pp. 107–113, 6 figs., *d*)

Slip, Friction, and Stretch Tests for Leather Belting

DESCRIPTION of the testing machines and methods of testing employed in the plant of J. E. Rhoads & Sons, Philadelphia, Pa. The slip testing machine consists of a lineshaft, countershaft, or jackshaft for driving the belt, a prony brake and scale for applying and measuring the load, a supporting scale for maintaining and measuring the tension, and a slip meter. This latter is described in some detail in the original article.

In the apparatus for determining the coefficient of friction of belt on pulley, a framework of angle iron supports the pulley-driving mechanism and two spring balances. The drive is from a motor through friction disks, an automobile transmission, and a worm gear to a 24-in.-diameter pulley. The belt is attached to two clamps which are hooked to the spring balances.

Among other things is described a test to determine the power of a small flat belt and to show that there is apparently no tension on the slack side when it carries a heavy overload.

An illustration in the original article consists of photograph taken while the belt was running at a speed of 2500 ft. per min. This shows that the undulations on the slack side were very nearly uniform. The belt was a single tannate, 2 in. wide, pulling 29 hp., which is 275 per cent of its rated load of $10^1/_2$ hp. under favorable conditions. Under unfavorable conditions the horsepower would be reduced to $8^1/_2$ or 9 and the overload that it could pull would probably be reduced somewhat. With no tension on the slack side, practically all of the tension exerted on the pulleys and bearings is transformed into the useful work of transmitting power.

The designer of today wants to select belts to handle what is considered the peak load plus the unexpected overload, and therein lies the value of the belt-testing laboratories because they have made it possible for him to specify, without guessing, the sizes required. (L. C. Morrow, Mem. A.S.M.E., managing editor of *American Machinist*, in *American Machinist*, vol. 60, no. 13, Mar. 27, 1924, pp. 469–471, 8 figs., *d*)

THERMODYNAMICS

Measuring Heat Transmission in Building Structures and a Heat-Transmission Meter

THIS paper deals with the measurement of heat flow through walls, more particularly those of existing structures. It outlines the principles employed and describes in detail work done at the American Society of Heating and Ventilating Engineers, Laboratory in attempting to develop a heat-transmission meter which will indicate instantaneous flows.

The paper describes the three principles available for measuring heat flow and devotes particular attention to the method first proposed in 1912 by A. H. Barker of England. It consists of a box placed over a portion of the wall. This box has in it heating coils and a fan to gently circulate the air. The air inside the box is kept at the same temperature as that in the room by means of a thermostat which regulates the current in the heating coil. Presuming there is no heat transfer through the walls of the box, all the heat passing through the portion of the wall covered by the box is supplied by the coils, and by metering this and recording the various temperatures a log can be plotted showing these values against time. This method is said to be the nearest approach to measuring the heat flow through a given area of a building wall and still maintaining natural conditions.

Next is discussed the method of measuring the temperature change along the path of heat flow and from the known thermal resistance between two points calculating the rate of flow, has two possibilities.

The simplest way to achieve this is by estimating the heat flow from the surface transmission coefficient. There are, however, difficulties in the way of doing this. The other possibility is the temperature gradient in the material. There is little possibility of attaining any reliable results from using the wall itself, as its conductivity is too uncertain but there is the option of placing a layer of material over the surface whose conductivity is known and measuring the flow of heat by its temperature difference. If the thickness and thermal resistance of the layer are comparatively large, this can be done with presumably fair accuracy. To eliminate certain sources of error the wires must be cemented on to the plate so that they are invariable, and their temperature

readings obtained by calibration tests in which known rates of heat flow are passed through them.

Such a plate when calibrated would be a heat-transmission meter since its temperature reading would directly give the rate of heat flow through it in whatever position it be used. Placing it on a wall will give the flow at that surface through the wall plus the plate, and as far as its thermal resistance is small compared with that of the wall, the flow through the part not covered can at least be approximately determined. It will, however, have the disadvantage of added resistance and changing the nature of the surface, but it will at least give a direct reading of the heat flow with the minimum of apparatus and without impressing a source of heat, can be closely eliminated for instantaneous values, and more so for average values over a sufficient time.

The work done on developing such meter plates is described and is governed by the following principles.

1 If they were to be of any value sufficient evidence would have to be offered of the order of their accuracy to insure the acceptance of values they would give in application.

2 The final plates must have the minimum thermal resistance consistent with the use of not too expensive auxiliary instruments, must be permanent in the calibration, and also must be fairly rugged.

Construction of Plates. It was decided to make the plates 2 ft. square. If it were found advisable to cover a larger area in their application, it could be done by using several similar plates and four of them would cover 16 sq. ft. Part of the plate must be the guard ring and the design of testing hot plate fixed the center area to be covered by the thermocouples as 15 ft. by 15 ft.

Some doubt was felt on the possibility of obtaining consistent results with thin plates, as well as doubt as to the possibility of making them so that they would be permanent and not fail, so it was decided to make the first set of several materials of different thicknesses, as a comparison between their readings would help to better bring out the causes of variations and confirm their accuracy.

As regards the method of measuring the temperatures, it was decided to use thermocouples. In addition to measuring the temperature difference, one surface temperature is needed in order to be able to connect the differential e.m.f. with some zero, and also because of possible variation of thermal conductivity with temperature.

Since the plates were to be calibrated by test, and not by the known conductivity of the material, there is no necessity to deal with actual temperatures but only with the readings given by the thermocouple system, and this in itself takes care of variations in the closeness of the wires to the surface, of the e.m.f. given by different junctions, and of the plate material, provided a given rate of heat flow at a given plate temperature always gives the same couple reading.

Since the manufacture of the plates required a large number of thermo junctions, an easy way was developed to make them.

The next subject discussed in detail is the method and apparatus used for calibrating the plates and for separating errors in the estimation of the flow from those of the plates themselves. Among other things, it was found from a comparison of results from thick and thin plates that there does not appear to be any indication that the former are more consistent or reliable, nor is there much in favor of any material. It is believed that with close contact on two sides, the readings the plates give can be taken as a true measure of the heat flow to within ± 1 per cent. The plate will at all times give the heat flow through the active portion, i.e., the area covered by the differential couples, and will average this if the flow is not uniform over the area. It will, however, add a thermal resistance to that area, and thus will make the flow less than that through the natural wall. It also tends to change somewhat the character of the heat flow through the wall.

Application of plates to a variety of conditions in order to test the type of reading they give brought to light an action which is more accentuated than was expected. Supposing a steady flow of heat into the surface, then a very small instantaneous change in temperature at the surface will produce a very large instantaneous change in the rate of flow, which will, however, quickly die down to a small normal change. As the plates measure the temperature difference through an appreciable thickness the initial change is marked, and a smaller change of flow is shown than occurs at the true surface. With a natural convection and the generally accredited stationary air film it was expected that there would have been a further lag, and that the wave length of changes would be large.

To illustrate how rapidly the plates record new conditions, a 60-watt lamp was suspended above each of the floor plates. The immediate action of the radiation was very marked.

The plates are thus very sensitive in their record, but this same sensitivity increases the difficulty of taking readings, which have to be averaged. It would thus be of decided advantage to bury the plate a small distance in the wall.

Observations on any one trial application of the plates were not sufficiently continuous to deduce values of constants, but they clearly showed the change in flow with conditions and the lag due to the mass of the wall.

It is plainly desirable that the various readings should be automatically recorded. There are various instruments that could record the temperatures, but the comparatively high resistance of the couple circuits makes a potentiometer type very desirable. In many applications the only values required would be the sum of the readings and, if it could be devised, an instrument similar in principle to a volt-meter would be ideal.

In what way can such heat-transmission meters be of assistance? Their primary use will be to give records of the flow which actually occurs, without regard to the cause, to obtain a check on calculated values, or to measure the loss of heat—temporary or average. Such records are needed both for the data they may give, and also to establish confidence in the ability to predict results by calculations.

They can be used to measure conductivity coefficients of materials under natural conditions, but such work must include a full set of temperature measurements, including some through the wall if it is of compound construction. In so far as the temperatures are not constant such test will have to be continuous, or by automatic records. The need for and advantage of doing such work under natural weather conditions are that it is removed from the opprobrium of being a laboratory test.

They should be of decided value in connection with laboratory tests in that the heat input need not be measured. Any source of heat at a constant temperature can be used and the actual transmission can be measured at the plane or planes most suitable. In high-temperature work the actual hot temperature, when it is generated electrically and the heat input measured, is limited by the ability of the apparatus to stand it, but by using a plate at the cold end the hot temperature can be produced by a flame. Using one each side of a single hot plate gives the division of heat on the two sides, which it is very desirable to know. They can also be a check on heat input, or of ice melted.

For natural wall transmission the plates are, in principle, inferior to Barker's box method, which disturbs the conditions less. They have the advantage, however, of greater simplicity and, it is believed, greater accuracy of measurement, especially if the room conditions are variable, as well as the ability to record flow in either direction. They become a necessity where observation must extend over a long period in order to cover a cycle of changes, such as the yearly one in a tunnel under a river.

In the appendices are discussed the relationship of differential e.m.f. to true surface temperature, the subject of thermocouples in series and in parallel, and the subject of air infiltration through a porous wall as affecting the heat transmission. A brief bibliography of the subject is also included. (P. Nicholls, Research Head, A. S. H. V. E. Laboratory. *The Journal of the American Society of Heating and Ventilating Engineers*, Jan., 1924, pp. 35–70, 30 figs., *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Condensing Apparatus

Preliminary Draft of an Additional Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

IN 1918 the Committee on Power Test Codes was reorganized by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. The committee consists of a main committee of twenty-five members under the chairmanship of Fred R. Low, and nineteen individual committees of specialists who are drafting test codes for the various prime movers and the other apparatus which comprise power-plant equipment.

The individual committee which developed the Test Code for Condensing Apparatus is headed by Geo. A. Orrok as Chairman, the other members being P. E. Reynolds, Secretary, C. H. Baker, R. N. Ehrhart, J. J. Mullan, H. B. Reynolds, and M. C. Stuart.

The committee and the Society will welcome suggestions for corrections or additions to this draft of its code from those who are specially interested in the manufacture and use of stationary steam-condensing units. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 Before proceeding with a condenser test, the Test Codes on "General Instructions," "Definitions and Values," "Centrifugal and Rotary Pumps," and "Instruments and Apparatus," should be carefully studied.

2 It should be borne in mind at the very beginning of any investigation of condensing machinery, that while some classes of condensers are apparently simple pieces of apparatus, a complete test of such a device as a surface condenser represents a greater complement of diversified auxiliary apparatus than any other unit in the power plant. Consequently a complete test requires the test of the condenser itself and, as conditions demand, either complete or partial tests of the auxiliaries. This code has been framed to include all types of condensing equipment with their auxiliaries but such items as have no bearing on the object in view can, of course, be omitted. The various classes of condensing apparatus which it covers and the principal auxiliary pumping equipment concerned are grouped as follows:

Surface-Condensing:

(*a*) Surface Condenser
(*b*) Circulating pump, steam-driven or motor-driven
(*c*) Air pump, either reciprocating dry-vacuum or hydraulic vacuum pump, either steam-driven or motor-driven, or steam-air ejector
(*d*) Condensate pump, steam-driven or motor-driven.

Low-Level Jet-Condensing and Barometric-Condensing:

(*a*) Jet condenser
(*b*) Supply or tail pump, steam-driven or motor-driven
(*c*) Air pump, either reciprocating dry-vacuum or hydraulic vacuum pump, either steam-driven or motor-driven, or steam-air ejector.

Ejector-Condensing:

(*a*) Condenser
(*b*) Supply pump, steam-driven or motor-driven.

Object

3 There may be several objects of the tests, as pointed out in the Code on "General Instructions," but usually they are conducted:

(*a*) to determine the fulfilment of the manufacturer's guarantee
(*b*) to determine the performance of the apparatus in part or as a whole from the standpoint of scientific or engineering interest as the special condition of the installation or the interested parties may suggest.

4 As there is often a difference in the pressure maintained in the various parts of the apparatus, the condenser guarantee usually specifies a definite absolute pressure to be maintained at the steam entrance to the condenser, when condensing a stated amount of steam in pounds per hour, the condenser being supplied with a sufficient amount of circulating water (usually specified) at a stated temperature, it being further understood that the condenser, prime mover, and connections shall be free from air leaks. It is sometimes stated that the air to be removed by the vacuum pump shall not exceed a certain figure. In addition to the condenser guarantee there are frequently separate guarantees covering the auxiliaries.

Instruments and Apparatus

5 The instruments and apparatus required for a condenser test consist of the following:

(*a*) Barometer, preferably of the mercurial type
(*b*) Mercury columns for measuring vacuums having the smallest scale graduations not greater than 0.1 in. and with vernier attachment
(*c*) Bourdon gages for measuring pressures when too great for mercury manometer tubes
(*d*) Thermometers:
  (1) For registering temperatures of circulating water, condensate and vapors—graduated by half-degrees and with maximum scale readings from 32 to 150 deg. fahr.
  (2) For determining steam temperature graduated by degrees and with maximum scale readings from 32 to 250 deg. fahr.
(*e*) Tanks and platform scales for measuring water (or water meters calibrated in place under conditions of use)
(*f*) Appliances for tests of auxiliary pumps such as steam-engine indicators, electrical instruments, speed indicators, tachometers, etc.
(*g*) Air-measuring devices—gasometer or calibrated orifices.

General directions for the application, use, and calibration of these instruments and apparatus, and information regarding their range and accuracy are given in the Code on Instruments and Apparatus.

6 Identically the same testing apparatus for measuring the quantity of steam condensed may be employed as that used for testing the engine, turbine or other steam machinery supplying the condenser. (See Codes for Steam Engine, Steam Turbines, etc.) For measuring circulating or injection water, the same kind of apparatus may be employed as that used in pumping-engine or water-wheel tests, such as weirs, nozzles, orifices, pitot tubes. (See Code on "Instruments and Apparatus.") The amount of circulating water may be estimated by the heat-balance method as given by the following equation:

$$C = \frac{H_c W_c}{t_o - t_i}$$

in which

C = lb. of circulating water per hr.
H_c = B.t.u. per lb. of steam absorbed by the condenser, from Par. 14
W_c = steam discharged to the condenser, lb. per hr.
t_o = temperature of circulating water out
t_i = temperature of circulating water in.

(*a*) In locating thermometers within the steam space of a condenser, care should be observed that the thermometer wells in which they are placed are shielded from direct impact of steam currents, and from radiation from the cold tubes.
(*b*) Special forms of thermocouples or other special devices will be required for accurate observations in the condenser, or of the saturated vapors passing from the condenser to the vacuum pump. Such observations are, however, entirely outside of any commercial guarantee of performance.
(*c*) Thermometers showing the temperature of discharge water should be located as far as practicable, but not greater than 100 ft., from the condenser, to allow thorough mixing of the water strata, otherwise, especially with large pipes and with special forms of circula-

tion, the temperature will vary considerably in different sections. Not less than three thermometers placed 120 deg. apart should be used for determining the temperature of the discharge circulating water. In measuring the temperature of water between the passes of surface condensers, there is likely to be some inaccuracy owing to the fact that stratified flow always exists at that point.

(*d*) Correct application and use of the mercury gage, preferably full-length mercury column, for determining vacuums is all-important in a condenser test. Long pipe connections should be avoided. The main part of the connecting pipe should be not less than $^1/_2$-in. iron-pipe-size, and it should be arranged to pitch toward the condenser, and contain no pockets. The pressure at the steam inlet to the condenser shall be measured by means of at least two carefully constructed mercury columns, accurate to 0.01 in. of mercury, used with all precautions and corrected for all observable causes of error. See Instruments and Apparatus. Each column shall be mounted on or within two or three feet of the condenser, and shall be connected, as provided in Instruments and Apparatus, to the inlet passage of the condenser, through pressure tips located within the condenser inlet nozzle and within 6 in. of the plane of the face of the condenser inlet flange. Pressure tips shall be located centrally in approximately equal areas into which the condenser inlet nozzle may be divided. It is recommended that these areas do not exceed 16 sq. ft. If the gages so connected exhibit serious discrepancies the situation must be specially studied. Possibly more gages may be necessary. The readings of all gages, corrected to inches of mercury at 32 deg. fahr., shall be averaged and subtracted from a similarly corrected reading of a mercurial barometer to give the condenser inlet pressure. Correction must be made for the difference in elevation of the barometer and the vacuum gages, if any. See Instruments and Apparatus, Par. —. Inlet pressure shall never be computed from temperature observations.

(*e*) The barometer and vacuum gage should be located near together, to avoid the necessity of correcting for altitude and temperature. A mercurial barometer which has been carefully checked should be used (See Code on Instruments and Apparatus, Par. —).

PREPARATION

7 In preparation for a condenser test, the Code on General Instructions should be carefully studied. The dimensions and physical condition of the condenser and auxiliaries should then be ascertained. If the condenser is of the surface type and the object in view permits, all fouled tube surfaces both inner and outer should be thoroughly cleaned. The quantity of leakage from the water spaces to the steam space, in the case of surface condensers, should next be determined. This may be done by measuring the water discharged from the condensate pump when running dry, that is, with all steam shut off from entering the condenser, the normal quantity of circulating water being in use and other conditions being normal. Any leakage thus revealed should be substantially rectified before proceeding with the main test, unless precluded by the object in view. In any event the quantity of leakage should be determined for at least an hour's time after normal conditions, as described above, are established, and deducted from the total condensate as measured on the main test. It is recommended that, if this leakage exceeds one (1) per cent of the normal capacity of the condenser, no further test be made until such leakage is reduced to the stated figure. The average of such a test made before and after the main test may be considered as the condenser leakage, but attention is called to the fact that under operating conditions the actual leakage may vary from that obtained during the leakage test, due to the different temperature conditions that may exist. This fact emphasizes the necessity for reducing the leakage to the absolute minimum before the test. Other methods for determining the amount of leakage have been successfully applied, but are not universally applicable, as, for example, the electrolytic method, which is based on the change in electrical resistance of condensate due to contamination with salt-water leakage. Also the chemical method of titration with a solution of silver nitrate using potassium chromate as an indicator. For additional information in regard to condenser leakage see Code on Instruments and Apparatus, Par. —.

(*a*) The tightness of the condenser and its connections with respect to air leakage, whatever the type of condenser, should be carefully ascertained. The surface condenser shell and its connections should be filled with water at a temperature approximately that of the surrounding air and under some slight pressure, and the leaks revealed. Care should be taken when filling a condenser with water to see that the condenser supports are not overloaded and an undue load placed on the turbine exhaust nozzle, in cases where the condenser is mounted on springs and there is no expansion joint between the turbine and condenser. A convenient method of determining the fact of air leakage, though not its degree, is to shut off the injection water, stop the admission of steam and then observe how long a time the vacuum holds. If the vacuum falls at once, a thorough search by the aid of a candle flame will serve to locate the leakage.

(*b*) The performance of the condenser is directly influenced by the amount of air leakage which varies greatly in actual service and should be brought down to the recognized quantity permissible in the size and type of prime mover under test. When required the quantity of air removed from the condenser may be measured by gasometer or other approved apparatus.

(*c*) The tightness of steam valves and pistons of the steam-driven auxiliaries may be ascertained, when necessary, by standing leakage tests. (See Code on Steam Engines, Pars. —.)

(*d*) If the object of the test permits, any serious leakages, whether of air, steam or water, should be rectified before proceeding with the main trial.

8 When required, preparations should be made for indicating the steam cylinders of any reciprocating steam-driven auxiliaries, and for determining the electric power or mechanical power absorbed by any motor-driven or belt-driven apparatus. (See Code on Reciprocating Steam Engines and Code on Instruments and Apparatus.)

OPERATING CONDITIONS

9 The operating conditions, such as speed of auxiliaries, degree of vacuum to be carried, quantity of circulation or injection water needed, should be determined prior to the beginning of the main trial, and these should prevail throughout the test.

10 *Operation Independent of Condenser or Shop Test.* Since the condenser performance is dependent upon the amount of air leakage, an item over which the condenser manufacturer does not have full control, it is necessary to assume a definite air-handling capacity of the air-removing apparatus, and separate or shop tests are in many cases desirable. However, different types cannot be compared as to efficiency in service from their relative performance upon a dry-air orifice test. The non-condensable vapors leave the condenser at a temperature lower than that corresponding to the absolute pressure in the condenser by an amount dependent upon the efficiency of the condenser cooler (if included) and varying with the conditions of operation.

STARTING, STOPPING, AND DURATION

11 The starting, stopping and duration of a condenser test should follow the same rules as those governing a steam-engine or turbine test, and reference should be made to the Steam Engine Code and Steam Turbine Code for the general directions to be followed.

12 In surface-condenser tests the quantity of steam condensed should be determined by collecting and weighing the condensate and correcting the total, as measured, for leakage, if any.

In jet condensers, including those of the barometric type:

(*a*) The quantity of steam condensed may be ascertained by measuring the feedwater consumption and correcting for drips, for leakage of boilers and piping, and for steam which is not supplied to the condenser, preferably by taking steam from a group of boilers.

(*b*) It may be determined approximately by steam-meter measurement if the meter is calibrated in place and under conditions of use; or by calculation from the heat units given up to the injection water, if determined.

(*c*) When the circulating water is discharged into an open tank, a V-notch or rectangular weir may often be arranged for the measurement. Otherwise an orifice may be inserted in the discharge pipe and orifice measurement employed. Any of these indirect methods must be considered as furnishing approximate measurements, especially when the weir or orifice is in a limited space and it is impracticable to calibrate it in place or under its working conditions. The calculation is also affected by the accuracy with which temperatures are read as well as the correctness of installation and the fineness of graduation of the thermometers. This becomes of great importance in cases of low temperature rise.

(*d*) The quantity of steam consumed by auxiliaries may be found by connecting them separately or collectively to a surface condenser, if available, and measuring the condensate; or by water-glass test made at a time when they can be operated independently, and preferably taking steam from a single boiler. (See Code on Reciprocating Steam Engines.)

(*e*) Where jet, barometric or ejector condensers are used, any air leakage into the water-supply line is as serious as a direct leak into the prime mover or condenser. Generally a portion of the water-suction line is under partial vacuum due to the fact that either the condenser itself or the circulating pump draws water from the injection source, which is usually at a lower elevation than the condenser or its supply

pump. A convenient method of determining whether there is any infiltration of air into this line, is to place a gage or mercury column directly beneath the valve on the injection line, which is usually located immediately adjacent to the condenser line, and observing the drop in the vacuum reading after the valve has been shut and the circulating pump shut down. A drop in the vacuum reading will either indicate air leakage into that part of the line under vacuum or a leak in the valve itself. It is seldom, however, that a leak in the injection valve causes any drop in the vacuum reading inasmuch as the water in the piping immediately over the valve and in the condenser chamber seals it for a considerable period of time.

RECORDS

13 The directions given in the Code on General Instruction under this heading should be followed in taking and recording the readings of instruments and other data.

CALCULATION OF RESULTS

14 *Heat Supplied to Condenser per Hour.* The size of the condensing equipment should be determined by the amount of work it is to perform—i.e., the amount of heat it is to remove. This depends upon the heat contents of the steam as delivered to the condenser, an amount seldom specified, although of prime importance. The heat supplied to the condenser is that supplied to the prime mover, exhausting to the condenser, less that converted into work and lost by generator losses, friction, radiation and other wastes, not readily determined. It is simply expressed by the following formulas (where the condenser is bolted direct to the turbine exhaust opening):

(*a*) For a simple non-bleeding and non-reheating turbine, $H_e = H_t - (3413/SE)$

(*b*) For a reheat, non-bleeder turbine, $H_e = H_t + (h_r - h_e) - (3413/SE)$ in which the expression $(h_r - h_e)$ is repeated for each stage of reheating.

(*c*) For a bleeder, non-reheat turbine,

$$H_e = \frac{H_t W}{W - (w_1 + w_2 + .. w_n)} - \frac{3413 \text{ KW}}{E[W - (w_1 + w_2 + .. w_n)]} - \frac{w_1 h_1 + w_2 h_2 + \ldots . w_n h_n}{W - (w_1 + w_2 + \ldots w_n)}$$

(*d*) For a bleeder and reheat turbine,

$$H_e = \frac{H_t W}{W - (w_1 + w_2 + .. w_n)} + \frac{W - w\ (h_r - h_e)}{W - (w_1 + w_2 + .. w_n)} - \frac{3413 \text{ KW}}{E[W - (w_1 + w_2 + \ldots w_n)]} - \frac{w_1 h_1 + w_2 h_2 \ldots w_n h_n}{W - (w_1 + w_2 + \ldots . w_n)}$$

In the equations given above

H_e = B.t.u. per lb. of steam at the prime-mover exhaust
H_t = B.t.u. per lb. of steam at the prime-mover throttle
S = steam supplied to throttle of prime mover, lb. per kw-hr.
E = mechanical and electrical efficiency of prime mover complete, including all friction, electrical loss, windage, radiation, etc.
h_r = B.t.u. per lb. of steam at point of reëntrance to turbine after reheating
h_e = B.t.u. per lb. of steam after partial expansion in the turbine at point of extraction for reheat
W = total steam supplied to throttle of prime mover, lb. per hr.
$w_1, w_2 \ldots w_n$ = steam bled from first, second, and nth bleeder point of turbine, lb. per hr.
$h_1, h_2 \ldots . h_n$ = B.t.u. per lb. of steam at the first, second, and nth bleeder point of the turbine
KW = load on prime mover in kilowatts.

In using the formulas given above for determining the heat absorbed by the condenser, the heat carried away by the condensate should be subtracted from H_e, or heat absorbed by condenser

$H_c = H_e - (t_c - 32)$

in which

H_c = B.t.u. per lb. of exhaust steam absorbed by condenser and carried away by the circulating water
t_c = temperature of condensate.

15 If the prime-mover steam rate is given in pounds per horsepower-hour, the constant, 2545 must be substituted for 3413. The value of E varies with both the type and size of prime mover.

16 A check upon the quantity of heat so determined is obtained by multiplying the weight of circulating or injection water in pounds per hour by its rise in temperature in its passage through the condenser—but such readings as already explained can only be considered as approximate.

17 *Determination of Heat Transfer in Surface Condenser.* The efficiency of the surface condenser is expressed in B.t.u. transmitted per sq. ft. of the tube surface per hour per degree mean difference M.D. in temperature between the two sides of the tube. Both the arithmetical and logarithmic mean difference are used for this purpose and it is recommended that the test results be given for both in order to make comparison possible with all other tests.

18 A complete comparative discussion here is not desirable, but it is permissible to state that the determination of both is based upon assumptions which do not correctly represent the conditions, in practice.

The formulas follow:

$$(a) \text{ Arithmetical Mean Difference} = t_s - \frac{t_o + t_i}{2}$$

$$(b) \text{ Logarithmic Mean Difference} = \frac{t_o - t_i}{\log_e \frac{t_s - t_i}{t_s - t_o}}$$

in which t_s = temperature in steam space
t_i = temperature of incoming circulating water
t_o = temperature of outgoing circulating water.

The main points of difference are as follows:

The arithmetical mean difference (*a*) assumes:

(1) A constant steam temperature throughout the condenser
(2) A uniform rise in temperature of the circulating water from its entrance to exit.

The logarithmic mean difference (*b*) is based upon:

(3) A constant steam temperature throughout the condenser
(4) That the heat transfer is uniform throughout the condenser.

19 While complete or satisfactory tests have not been published, making the necessary study generally possible, fairly exhaustive tests have been made recording steam temperatures throughout the condenser and the rise in temperature at many different points in the tubes located in different sections of the condenser (by means of thermocouples) as well as a study of the rate of flow in different tubes. From these it is evident, as expected, that the temperature is not uniform throughout the condenser and that the rate of heat transfer is not uniform.

20 The transfer of heat through a tube surface from air to water has been given by different experimenters as varying from 6 to 10 B.t.u. per sq. ft. per deg. fahr. per hour, or less than 1 per cent of that from steam to water: If we have 180,000 lb. of steam per hour entering a surface condenser and carrying with it, say, 8 cu. ft. of free air per minute, or 36 lb. per hour, we will have at the entrance 5000 lb. of steam per lb. of air, the latter being negligible, and the temperature of steam as indicated by correctly placed thermometer will be practically that corresponding to the absolute pressure at that point.

21 In an efficient modern condenser with properly designed air cooler, the vacuum pump should withdraw from the condenser a mixture at a temperature somewhat below that corresponding to the absolute pressure, and consisting of the air (or non-condensible vapor) with sufficient steam vapor to saturate the mixture at the stated temperature, all of the rest of the steam being condensed out in passing through the condenser. At the point of leaving the condenser the mixture would consist largely of air and the heat transfer would more nearly correspond to that of air. It is therefore evident that the heat-transfer must vary very widely through the condenser, and that assumptions (1), (3), and (4) of Par. 18 are incorrect. Assumption

(2) is also incorrect since, in assuming a uniform rise in temperature of the circulating water it follows that the heat transfer has been taken as varying inversely with the temperature difference between the steam and circulating water (or $U \times \text{M.D.} = c$), which of course is incorrect unless the heat transfer itself varies similarly owing to the presence of air as just described.

22 It will oftentimes be found in practice, that the curve of circulating-water temperature rise will more nearly conform to a straight-line performance. Some authorities have advised the use of the arithmetical mean as sufficiently accurate for purposes of comparison, especially when the rise in temperature of circulating water is small.

23 Plotted curves will show a difference of from 3 to 10 per cent in the mean difference, as derived for usual practical conditions at $1^1/_2$ to 2 in. of mercury, absolute pressure, and, say, 20 per cent around 3 in.

24 Most engineers prefer the logarithmic mean, which in any event should be adhered to for all heater calculations where the range of temperature is high and the formula assumptions more nearly correct.

25 Methods of calculating other results are plainly indicated in the Table of Data and Results.

DATA AND RESULTS

26 For a complete and exhaustive test, it is recommended that the complete form, Table 1, be used, adding or omitting items as required by the particular test. Where nothing more than the usual commercial test is required, it is recommended that the short form, Table 2 be used, adding such items as are required.

TABLE 1 DATA AND RESULTS OF CONDENSING-APPARATUS TEST

GENERAL INFORMATION

(1) Date of test
(2) Location
(3) Owner
(4) Builder
(5) Test conducted by
(6) Object of test

DESCRIPTION AND DIMENSIONS, ETC.

(7) Unit number.....Manufacturer's Serial No.
Drawing No.
How long in service?
If surface type, how long since tubes were last cleaned?
(8) Condensing steam from—No.—size—make—
type (hor. or vert.) turbine or engine
(9) *Type condenser (Horizontal or vertical—jet or surface).*
(*a*) Material of shell
(*b*) Weight of condenser, empty.....lb.
(*c*) Weight of condenser, including circulating water....lb.
(*d*) Shape and approximate overall dimensions
(*e*) Vacuum breaker—type and description
(10) Distance between exhaust flange of prime mover and condenser exhaust opening, size of connecting pipe, with enumeration and description of fittings and valves in same.
Are valve disks, stems and joints water sealed?
(11) Exhaust relief valves: Size, make and location
Is relief valve water sealed?
(12) Source of supply of circulating or injection water (salt or otherwise)
(*a*) Analysis of condensing water

Surface Condenser:

(Whether (1) standard type, water inside tubes, or (2) water-works type water outside tubes.)
(13) Number of passes (water if 1) (steam if 2)
(14) Amount of effective *cooling* surface in sq. ft. (including air cooler but excluding internal heater) measured on the outside of the tubes between tube heads if (1) on the inside, if (2) tube-head area not included.
(15) Amount of effective *heating* surface in internal heater, if any—sq. ft. (see drawing).
(16) Location and description of internal heater, if any.
(17) Amount of effective cooling surface in air cooler
(18) Location and description of air cooler (see drawing)
(19) Diameter, gage, material and length of tubes between heads
(20) Number of tubes in passes
(*a*) Tubes in first pass
(*b*) Tubes in second pass
(*c*) Tubes in third pass
(*d*) Tubes in fourth pass
(21) Dimensions, shape and material of tube head and total area in sq. ft. of each tube head, in steam space (before drilling for tubes).
(22) Number, material and total thickness of support plates
(23) Per cent of tube-head area in contact with steam
(24) Per cent of volume of shell actually occupied by tubes below a horizontal line at top of tube head—inside shell
(25) Description or sketch of tube layout
(26) Kind of tube packing
(27) Condition of tube surface (as to cleanliness)

Low-Head Jet, Barometric or Ejector Condenser—Parallel-Flow or Counter-Current:

(28) Approximate volume of space available for condensation....cu. ft.
(29) Type of water distributor (jet or gravity)
(30) Number and type of jets
(31) Mechanical condition of apparatus

Special Features:

(32) Description of special features including internal or external cooler, if any

Circulating Pump of Surface Condenser, or Removal (or Tail) Pump of Low-Head Jet Condenser, or Injection Pump of Barometric or Ejector Condenser:

(33) Manufacturer, serial number and drawing number
(34) Type, horizontal or vertical—centrifugal or reciprocating
(35) Number of stages if centrifugal—single or duplex—single or double suction
(36) How driven (engine, turbine or motor)
(37) Rated horsepower, dimensions of cylinders and stroke of reciprocating apparatus
(38) Normal r.p.m. and characteristics of motor
(39) Size of all pipe openings
(40) State special features, type of valves, direct-gear-or belt-driven
(41) Manufacturer's guarantees, if any
(42) Mechanical condition

Air-Vapor-Removal Apparatus:

Reciprocating Dry Vacuum Pump
(43) Manufacturer, serial number and drawing number
(44) Type (horizontal or vertical) number of stages
(45) How driven (steam cylinder or motor)
(46) Size:
(*a*) Diameter steam cylinder and stroke....in.
(*b*) Diameter air cylinder first stage....in.
(*c*) Diameter air cylinder second stage....in.
(*d*) Diameter of piston rods—air cylinders....in.
(*e*) Diameter of piston rods—steam cylinders....in.
(47) Type and description of air valves
(48) Actual air piston displacement per revolution....cu. ft.
(49) Clearance in per cent of air piston displacement
(50) Type, size and description of motor (if motor-driven)
(51) Special features
(52) Manufacturer's guarantees, if any
(53) Mechanical condition

Hydraulic Type:

(54) Manufacturer, serial number and drawing number
(55) Type and trade name
(56) Size including supply pump if separate
(57) How driven (engine, turbine or motor)
(58) Give i.hp. or b.hp.
(59) Size of all pipe openings
(60) Special features
(61) Manufacturer's guarantees, if any

Steam-Jet or Ejector Type:

(62) Manufacturer, serial number and drawing number
(63) Type, trade name, number of stages
(64) Number and sizes of precooler, intercooler and aftercooler (jet or surface) and amount of surface in each
(65) Size of steam and water connections
(66) Special features including supply of water for coolers, removal of condensate, etc
(67) Are single or multi nozzles used in ejectors?
(68) Manufacturer's guarantees, if any
(69) Mechanical condition

Condensate Pump:

(70) Manufacturer, serial number and drawing number
(71) Type—horizontal or vertical—number of stages
(72) Size of suction and discharge openings
(73) How driven (engine, turbine or motor) b.hp. and speed
(74) Special features
(75) Manufacturer's guarantees, if any
(76) Mechanical condition

TEST DATA AND RESULTS

(77) Duration of test.....hrs.

Steam Supply:

(78) Load on prime mover or other apparatus exhausting to condenser.....i.hp. or kw.
(79) Heat equivalent of work per hour.....B.t.u.
(80) Steam pressure at main throttle.....lb.
(81) Quality of steam at main throttle.....per cent moisture or deg. superheat
(82) Quantity of steam entering condenser if determined.....lb.
(83) Quantity of steam at throttle of each auxiliary if required.....lb.

Average Pressures and Temperatures:

(84) Barometric pressure as observed ..... in. of mercury
(a) Temperature ..... deg. fahr.
(85) Barometric pressure as corrected ..... in. of mercury
(86) Temperature of atmospheric air ..... deg. fahr.
(a) Relative humidity ..... per cent
(87) Absolute pressure of steam leaving prime mover or other apparatus at exhaust flange ..... in. of mercury
(88) Absolute pressure of steam entering condenser or other apparatus at exhaust flange ..... in. of mercury
(89) Saturated-steam temperature corresponding to this pressure ..... deg. fahr.
(90) Measured temperature of same ..... deg. fahr.
(91) Absolute pressure at air-removal flange ..... in. of mercury
(92) Absolute pressure at vacuum-pump suction nozzle ..... in. of mercury

Surface Condenser:

(93) Total amount of steam delivered to prime mover or other apparatus exhausting to condenser as measured ..... lb.
(a) Rate per hour ..... lb.
(94) Total amount of steam bled from first bleeder connection ..... lb.
(a) Rate per hour ..... lb.
(95) Total amount of steam bled from second bleeder connection ..... lb.
(a) Rate per hour ..... lb.
(96) Total amount of steam bled from *n*th bleeder connection ..... lb.
(a) Rate per hour ..... lb.
(97) Total amount of water delivered by hot-well pump ..... lb.
(a) Rate per hour ..... lb.
(98) Amount of water leakage including steam from seals per hr ..... lb.
(a) Immediately prior to test ..... lb.
(b) Immediately after test ..... lb.
(c) Average leakage—Corrected to rate per hour ..... lb.
(99) Amount of prime-mover steam condensed by condenser ..... lb.
(a) Rate per hour ..... lb.
(100) Temperature of circulating water .....
(a) Entering condenser ..... deg. fahr.
(b) Leaving first pass ..... deg. fahr.
(c) Leaving second pass ..... deg. fahr.
(d) Leaving third pass ..... deg. fahr.
(e) Leaving condenser ..... deg. fahr.
(101) Temperature of condensate in hot well ..... deg. fahr.
(102) Temperature of condensate leaving internal heater—if any ..... deg. fahr.
(103) If make-up or other foreign water is introduced to condenser or hot well, additional data should be furnished as to quantity, temperature, etc.

Circulating Pump:

(104) Amount of circulating water (measured if possible) ..... gal. per min.
(105) Circulating-water pressure above atmospheric
(a) At condenser-inlet nozzle ..... ft. water
(b) At condenser-outlet nozzle ..... ft. water
(c) Difference in level between circulating nozzles center lines ..... ft.
(d) Net condenser-circulating friction ..... ft. water
(106) Piston speed or r.p.m. if centrifugal .....
(107) (a) Pressure at pump intake nozzle ..... ft. water
(b) Pressure at discharge ..... ft. water
(c) Difference in level of gages ..... ft. water
(d) Total corrected pumping head ..... ft. water
(108) Absolute pressure at throttle ..... lb. per sq. in.
(a) Quality of steam at throttle per cent moisture or deg. sup. .....
(109) Absolute pressure at exhaust nozzle ..... lb. per sq. in.
(110) Total i.hp. or b.hp., or electrical hp. if motor-driven .....
(111) Weight of steam consumed per hour ..... lb.

Jet, Barometric or Ejector Condensers:

(112) Amount of water handled by injection or removal pump ..... gal. per min.
(113) Temperature of injection water
(a) Entering condenser ..... deg. fahr.
(b) Leaving condenser ..... deg. fahr.
(114) Absolute pressure of injection water in distributing box at inlet flange ..... ft. water
(a) Height of same above center line of pump ..... ft.
(115) (a) Pump discharge pressure (by gage) ..... ft. water
(b) Pump intake pressure (by gage) ..... ft. water
(c) Difference in level between centers of gages ..... ft.
(d) Water level in condenser or hot well above center lines of pump ..... ft.
(116) Correct total pumping head ..... ft. water
(117) Speed of pump ..... r.p.m.

Air-Vapor Removal Apparatus. All types of Reciprocating Dry Vacuum Pumps—Steam or Motor Driven. All types of Hydraulic Pumps—Steam or Motor Driven

(118) Steam Conditions:
(a) Absolute pressure at throttle ..... lb. per sq. in.
(b) Quality of steam at throttle, per cent moisture or deg. sup.
(c) Absolute pressure at steam exhaust nozzle ..... lb. per sq. in.
(d) Weight of steam consumed per hour ..... lb. per hr.
(119) Air-Vapor Pressures and Temperatures:
(a) Absolute pressure at pump suction nozzle ..... in. of mercury
(b) Temperature air-vapor at suction nozzle ..... deg. fahr.
(c) Lowest absolute pressure obtainable with closed suction. (This determined before or at close of main test and with as near the same operating conditions as possible.) ..... in. of mercury
(120) Horsepowers of Drivers:
(a) Horsepower of steam cylinders, (if reciprocating) ..... I.hp.
(b) Brake horsepower of turbine ..... B.hp.
(c) Power input if motor-driven ..... Kw.
(1) Speed of motor ..... r.p.m.
(2) Efficiency of motor ..... per cent
(121) Reciprocating Dry Vacuum Pumps:
(a) Horsepower of vacuum cylinders ..... I.hp.
(b) Speed ..... r.p.m. or s.p.m.
(c) Displacement of piston ..... cu. ft. per min.
(d) Mechanical efficiency of pump ..... per cent
(e) Temperature of jacket cooling water entering ..... deg. fahr.
(f) Temperature of jacket cooling water leaving ..... deg. fahr.
(g) Amount of jacket cooling water ..... lb. per hr.
(h) Temperature of air-vapor at pump discharge nozzle ..... deg. fahr.
(122) Hydraulic Type:
(a) Speed of pump ..... r.p.m.
(b) Temperature of hurling water entering ..... deg. fahr.
(c) Temperature of hurling water leaving ..... deg. fahr.
(d) Amount of hurling water circulated ..... gal. per min.
(e) Absolute pressure of hurling water at pump suction nozzle ..... lb. per sq. in.
(f) Absolute pressure of hurling water at discharge nozzle ..... lb. per sq. in.
(g) Amount of hurling water make-up ..... gal. per min.
(h) Temperature of hurling water make-up ..... deg. fahr.
(i) Method of cooling hurling water, if this water is recirculated .....
(123) Steam-Air Ejector:
(a) Absolute steam pressure at ejector throttle ..... lb. per sq. in.
(b) Quality of steam at ejector throttle ..... deg. fahr. sup. or per cent moisture
(c) Amount of steam used, first stage nozzles ..... lb. per hr.
(d) Amount of steam used, second stage nozzles ..... lb. per hr.
(e) Absolute air-vapor pressure at main suction nozzle ..... in. of mercury
(f) Temperature of air-vapor at main suction nozzle ..... deg. fahr.
(g) Absolute air-vapor pressure at suction nozzles, second stage ..... in. of mercury
(h) Temperature of air-vapor at suction nozzle, second stage ..... deg. fahr.
(i) Temperature of water entering intercooler, (if any—surface or jet) ..... deg. fahr.
(j) Temperature of water leaving intercooler ..... deg. fahr.
(k) Amount of water used in intercooler ..... gal. per min.
(l) Amount of condensate leaving intercooler, (if surface) ..... lb. per hr.
(m) Temperature of condensate leaving intercooler ..... deg. fahr.
(n) Absolute pressure at exhaust nozzle ..... lb. per sq. in.
(o) Temperature at exhaust nozzle ..... deg. fahr.
(124) Actual amount of air discharged, (as measured by gasometer or orifice—see code section dealing with instruments and apparatus.) ..... cu. ft. per min. at 60 deg. and 14.7 lb.

Condensate Pump:

(125) Speed of pump ..... r.p.m.
(126) Heat contained in condensate above 32 deg. fahr. ..... B.t.u.
(127) Total amount of water handled per hour ..... lbs.
(a) Rate per minute ..... gal. per min.
(128) Water pressures:
(a) Pump discharge pressure, (corr. to center line of pump) ..... ft.
(b) Pump suction pressure, (corr. to center line of pump) ..... ft.
(c) Total head on pump ..... ft.
(d) Water level in condenser or hot well above center line of pump ..... ft.
(129) Water horsepower from above ..... hp.
(130) Power required to drive, if motor-driven ..... b.hp.
(131) Absolute pressure at throttle ..... lb. per sq. in.
(132) Quality of steam ..... per cent moisture or deg. superheat
(133) Absolute pressure at exhaust ..... lb. per sq. in.
(134) Steam per hour required to drive, (if steam-driven) ..... lb.

Additional Data:

(135) Necessary additional data to cover operation of any special features or auxiliaries as referred to under item 32 .....

GENERAL RESULTS OF TESTS

(136) Steam condensed per hours:
(a) Guarantee ..... lb.
(b) Test (Item 99*a*) ..... lb.
(137) Absolute pressure maintained at condenser, exhaust nozzle:
(a) Guarantee ..... in. of mercury
(b) Test (Item 88) ..... in. of mercury

(138) Temperature corresponding to test pressure: (Item 89)..deg. fahr.
(139) Temperature of condensate in hot well:
(*a*) Guarantee....deg. fahr.
(*b*) Test (Item 101)....deg. fahr.
(140) Temperature of entering condensing water:
(*a*) Guarantee....deg. fahr.
(*b*) Test (Item 100*a*)....deg. fahr.
(141) Quantity of condensing water:
(*a*) Guarantee....gal. per min.
(*b*) Test....gal. per min.
(142) Amount of free air handled by air pump:
(*a*) Guarantee....cu. ft. per min. at 60 deg. and 14.7 lb.
(*b*) Test (Item 124) cu. ft. per min. at 60 deg. and 14.7 lb.
(143) Total heat delivery to prime mover:
(From Items 78 to 82)....B.t.u. per hr.
(144) Total heat carried to condenser by exhaust steam
(See Introduction 14 to 15)....B.t.u. per hr.
(145) Total heat carried from condenser by condensate
(From Items 97 to 101)....B.t.u. per hr.
(146) Total heat absorbed by condensing water
(From Items 100 and 104)....B.t.u. per hr.
(147) Steam supplied to auxiliaries:
(*a*) Absolute pressure at throttle....lb. per sq. in.
(*b*) Quality of steam
....per cent moisture or degrees superheated
(148) Steam consumed by auxiliaries:
(*a*) Guarantee....lb. per hr.
(*b*) Test....lb. per hr.
(*c*) Per cent of steam delivered to condenser....per cent
(149) I.hp. or b.hp. of auxiliaries:
(*a*) Guarantee....hp.
(*b*) Test....hp.
(150) Mechanical efficiency of circulating or tail pump
(From Items 104–116)....per cent
(151) Mechanical efficiency of condensate pump
(Items 129–134)....per cent
(152) Mechanical efficiency of vacuum pump....per cent
(153) Volumetric efficiency of vacuum pump....per cent
(154) Average velocity of circulating water through tube..ft. per sec.
(155) Heat transfer per deg. difference of temperature per sq. ft. per hour: (Based on total surface, Item 14.)
(*a*) Using arithmetical mean....B.t.u.
(*b*) Using logarithmic mean....B.t.u.
(156) Steam condensed per sq. ft. of total surface per hour
(Item 82 ÷ 14)....lb.
(157) Pounds circulating water per lb. of steam condensed
(Item 104 ÷ 99*a*)....
(158) Pounds circulating water per sq. ft. of total condenser surface (Item 104 ÷ Item 14)....

TABLE 2 PRINCIPAL DATA AND RESULTS OF CONDENSER TEST

(1) Dimensions of condenser and auxiliaries....
(2) Data regarding prime mover or other apparatus exhausting to condenser....
(3) Data regarding types and special features of all auxiliaries....
(4) Date of test....
(5) Steam condensed per hour....
(6) Auxiliaries:
(*a*) Steam or power consumed by auxiliaries....
(*b*) Per cent of (*a*) to total steam or power of apparatus exhausting to condenser....
(7) Absolute pressure at condenser exhaust nozzle....
(8) Temperature of condensate in well....
(9) Difference between temperature of steam entering condenser and temperature of water in hot well....
(10) Circulating water:
(*a*) Quantity....
(*b*) Temperature at inlet....
(*c*) Temperature at outlet....
(11) Heat transfer per degree difference of temperature per sq. ft. of condensing surface per hour:
(*a*) Arithmetical....
(*b*) Logarithmic....
(12) Volume of air removed per minute at 60 deg. fahr. and 14.7 lb. abs...

TABLE 3 SUPPLEMENTARY CODE

Operation Independent from Condenser or Shop Test

(*See Introduction, Par. 10.*)

Air-Vapor Removal Apparatus:

(1) Reciprocating Dry Vacuum type:
(*a*) Absolute steam pressure at throttle....lb. per sq. in.
(*b*) Quality steam at throttle....deg. fahr. S. H. or per cent moisture
(*c*) Speed—r.p.m. or strokes per minute (at which pump is designed to operate)....
(*d*) Displacement of air piston....
(*e*) With items (*a*), (*b*), (*c*), and (*d*) constant determine
(1) I.hp. (of steam cylinder) if steam driven....
(2) B.hp. if motor-driven....
(3) I.hp. of air cylinders....
(4) Absolute pressure at exhaust steam nozzle....
(5) Absolute pressure at discharge air nozzle....
(6) Absolute pressure at air suction nozzles, with closed air suction and handling various quantities of free air at 60 deg. fahr. and 14.7 lb. abs. as measured by orifices or gasometer....
(*f*) Plot curves:
(1) Air handled vs. absolute pressure at suction nozzle....
(2) Air handled vs. I.hp. of steam cylinders....
(3) Air handled vs. B.hp. if motor-driven....
(4) Air handled vs. Mechanical efficiency....
(5) Air handled vs. Volumetric efficiency....

(2) Hydraulic Types:
(*a*) Absolute steam pressure at throttle....lb. per sq. in.
(*b*) Quality steam at throttle
....deg. fahr. superheat or per cent moisture
(*c*) Speed (at which pump is designed to operate)....r.p.m.
(*d*) Temperature of hurling water....deg. fahr.
(*e*) Quantity of hurling water....gal. per min.
(*f*) With item (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*) constant determine
(1) B.hp. of driver (turbine or motor)....
(2) Absolute pressure of hurling water at suction nozzle
(3) Absolute pressure at pump discharge nozzle....
(4) Absolute pressure at air suction nozzle, with closed air suction and handling various quantities of free air at 60 deg. fahr. and 14.7 lb. abs. as measured by orifice or gasometer....
(*g*) Plot curves:
(1) Air handled vs. absolute pressure at suction nozzle....
(2) Air handled vs. B.hp. of driver....
(*h*) Data for other curves can be determined, if desired, by varying speed, amount of hurling water, or temperature of hurling water....

(3) Steam Air Ejectors:
(*a*) Absolute steam pressure at throttle....lb. per sq. in.
(*b*) Quality of steam at throttle
....deg. fahr. S.H. or per cent moisture
(*c*) Quantity of steam used by 1st stage nozzles..lb. per hr.
(*d*) Quantity of steam used by 2nd stage nozzles....
(*e*) Temperature of water entering intercooler, (if any surface or jet)....deg. fahr.
(*f*) Quantity of water used in intercooler....gal. per min.
(*g*) Amount of condensate from intercooler, (item *c*) (if surface)....lb. per hr.
(*h*) With items (*a*), (*b*), (*c*), (*d*), (*e*), (*f*), and (*g*) constant determine:
(1) Absolute pressure at main air suction nozzles....
(2) Absolute pressure at 2nd stage suction nozzles....
(3) Temperature of air vapor at 2nd stage suction nozzles....
(4) Absolute pressure at exhaust nozzles....
(5) Temperature of water leaving intercooler....
(6) Temperature of condensate leaving intercooler, with closed air suction and handling various quantities of free air as measured by orifice or gasometer....
(*i*) Plot curves:
(1) Air handled vs. absolute pressure at main suction nozzle....
(2) Air handled vs. absolute pressure at 2nd stage suction nozzle....
(*j*) Data for other curves can be determined, if desired, by varying the steam pressure at throttle, exhaust pressure or temperatures and quantity of water used by intercooler....
(*k*) Note: To conduct this test it is necessary to have a receptacle under vacuum into which the drains from the intercooler can be discharged.

(4) Remarks:

As stated in the introduction, Par. 10, air pumps operating in connection with condensers do not handle dry air but saturated air so that an independent or shop test handling dry or free air is not a criterion of the effectiveness of the apparatus in actual operation. These tests are made generally to determine if the maker's guarantee has been fulfilled as guarantees on the air removal apparatus are usually based on free-air handling capacity. Independent or shop tests can be made with air saturated by mechanical means but it is a very difficult matter to duplicate condenser conditions and a code covering this method of testing air-vapor removal apparatus has not been included.

Correspondence

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

Forces Acting on Ball-Bearing and Roller-Bearing Connecting Rods

TO THE EDITOR:

Referring to the communication entitled Forces Acting on Ball-Bearing and Roller-Bearing Connecting Rods, on page 223 of the April issue of MECHANICAL ENGINEERING, the figures correctly illustrate the conditions present in a ball or roller connecting rod, but I believe that false conclusions have been drawn. The article states: "In quadrant 1 this rotation of the pin and oscillation of the strap are in opposite directions and tend to impart a rolling motion to the ball. . . . But the crankpin rotates at a greater rate of speed than the strap oscillates, with the result that the ball will slip rather than roll." This deduction is not obvious as a ball will roll freely between two raceways or surfaces regardless of whether the inner or outer race is revolving or whether both are revolving in the same or opposite directions, unless some other force such as inertia is acting on the balls. The single exception to this is when both inner and outer races are revolving at the same angular speed, when of course the balls will not roll but the entire assembly will turn as a unit.

However, there is a tendency toward slippage of balls or rollers in connecting-rod bearings, and under some conditions actual slippage does occur. In quadrant 1 the balls tend to roll about their individual axes at a high speed because the raceways are revolving in opposite directions. The retainer (real or imaginary) which carries the balls tends to revolve slowly, but in the direction of the crankpin (under ordinary conditions).

In quadrant 4 the balls still tend to roll about their individual axes but at a reduced speed, since the outer race is revolving in the same direction as the inner but at a lesser speed than the inner. The retainer, however, will tend to revolve faster. Further study will show that the rolling speed of the balls will be relatively high in the 1st and 2nd quadrant (as numbered) and relatively slow in the 4th and 3d. The speed of the retainer about the crankpin will be relatively slow in the 1st and 2nd quadrants and relatively fast in the 4th and 3d.

It is obvious that inertia forces must be set up which will have a tendency to cause slippage in all quadrants. These forces may be separated into the inertia forces of the balls about their own axes and into those of the retainer and balls about the axis of the retainer. It will be found that these forces will vary from a maximum to a minimum four times for each revolution of the crankshaft.

F. A. JIMERSON.

Athens, Pa.

TO THE EDITOR:

On page 223 of the April number of MECHANICAL ENGINEERING is an interesting discussion of the action of balls or rollers in the crank-end bearing of a connecting rod. It does not seem, however, that the theorizing can be correct, except in the premise that the ball, although free to turn, has a fixed axis, which premise is of course fallacious.

If a ball between two moving surfaces is free to move, it can roll between these surfaces without slippage, regardless of how the relative motion of the two surfaces may vary either in direction or in velocity. If the strap and crankpin are both rotating in the same direction, the ball will not slip between the two but will move bodily in the same direction; any difference in linear velocity between the strap and crankpin being taken up by rolling of the ball.

It is conceivable that a sudden change in relative direction of strap and crankpin might cause a tendency to slip due to inertia in the ball, but the reason given by the correspondent for slippage is fallacious.

CHANNING TURNER.

Geneva, Ill.

Windage Loss, Another Difficulty with the Gas Turbine

TO THE EDITOR:

In the April issue of MECHANICAL ENGINEERING there was published on page 216 a brief abstract of a paper which was read on January 29, 1924, before the Institute of Marine Engineers, by Hugh Campbell.

In this abstract many of the difficulties encountered with gas turbines were mentioned, but one of the principal ones was omitted, and this is the matter of windage, or the resistance to rotation of the turbine parts.

Steam turbines, condensing, attain about the same thermal efficiency as reciprocating steam engines, condensing. There is, however, no non-condensing steam turbine that is a rival, as far as steam consumption is concerned, of the non-condensing reciprocating steam engine, and for this reason non-condensing steam turbines are relatively little used.

The great reason for the low efficiency of the non-condensing steam turbine is windage, or the friction of the rotating parts of the turbine. This friction varies as some power of the absolute pressure of the steam in which the turbine parts rotate. So great an influence, in fact, is this loss in the turbine due to windage or skin friction, that many refinements in condensers have been made since steam turbines have come into general use. In other words, it is possible to reduce very greatly the windage or the skin friction of the rotating parts of a steam turbine by diminishing the pressure of the steam in which the turbine parts rotate. It is not possible, however, to reduce the windage or skin friction of the rotating parts of a gas turbine in a similar manner. These must necessarily revolve in an atmosphere whose pressure is slightly higher than that of the outside air. Now, the gas turbine bears about the same relation to the reciprocating gas engine that the non-condensing steam turbine bears to the non-condensing reciprocating steam engine. Since a non-condensing steam turbine cannot nearly attain the steam consumption of the non-condensing reciprocating steam engine, although the theoretical steam consumption would be the same, there is little reason to believe that it would be possible to attain as low gas consumption with gas turbines as we attain with reciprocating gas engines. Theoretically, the gas consumption of a gas turbine and of a reciprocating gas engine will be the same. Practically, we must expect that the windage and other losses in the gas turbine will be greater than the losses that occur in the reciprocating gas engine, since that has been demonstrated to be the case when non-condensing steam turbines are compared with non-condensing reciprocating steam engines. As a matter of fact, there is no authentic record of the efficiency of a gas turbine that has equaled the efficiency of a reciprocating gas engine under like conditions.

The foregoing paragraphs contain nothing that is new to students of gas turbines. The statement of the difficulties that prevent the realization of an economic gas turbine in the review of Mr. Campbell's report made no mention of what appears to be a serious fundamental difficulty, and it seems appropriate to call attention to this fundamental difficulty.

JOHN T. FAIG.

Cincinnati, Ohio.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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Skilled Labor and Industrial Leadership

IF AMERICA wants industrial leadership and if it is to retain the industrial advantages it has, it must, among other things, have its quota of highly skilled mechanics. Industry cannot grow unless it is founded securely on skill, and men cannot acquire skill unless opportunity for training is available.

Regardless of what economic necessities may have caused the present shortage of skilled workmen, the industries themselves must assume a certain responsibility in decreasing it. Potential skill lies inherently in many a crude and untutored workman. Given the opportunity and necessary training he may develop into a skilled mechanic, and a dormant pride in his work may be awakened. Apprentice-training courses, industrial education in any form which gives the young workmen an opportunity to look ahead, to learn, to fit himself for the highest and best work of which he is capable, are the legitimate responsibility of industry.

Moreover, the strength of an organization is largely dependent upon the opportunity it gives each individual member to do better and still better work. Apprentice-training courses should enable the worker to measure his ability and advance, according to his qualifications, step by step along the lines for which he is fitted. Thus will industry best be served, for the results will be an increase in skilled workmen and a decrease in labor turnover.

Nor need discouragement arise over the failure of certain apprentice-training systems in the recent past. When machine standards superseded and, in many ways, discounted craft standards, the problem of apprentice training became entirely different than it was in the old days when a pride in fine craftsmanship had a social significance. One unfortunate result of the age of machinery has been that definite, organized training for apprentices has in the main been given up, and the few sporadic and spasmodic attemps at apprentice systems have sometimes failed because, frankly, they were attempts to exploit the boy for the profit of the employer. A few noteworthy exceptions have given confidence in the value of the idea for modern industrial life. Many plants which started apprentice systems in good faith and with good intentions have failed because there was no trained person who could see and carry the thing through. One great drawback to the work has been the lack of organized information available on the subject.

The skilled mechanical trades should attract many of the boys who drift into white-collar jobs or into machine work on a production operation where the comparatively easily attained skill brings high wages quickly. It becomes increasingly important, therefore, that apprentice systems offer advantages which will be attractive to the high-school boy and influence his decision as to whether he enter the white-collar group, the unskilled labor group which through its labor unions has been able to demand and receive high wages, or an educational apprentice system which will give meaning to the early years of his industrial, open up to him the satisfaction of skilled craftsmanship and creative work, life and fit him for increasing usefulness. The burden of responsibility rests upon those industries whose very existence depends upon their ability to secure skilled workmen.

It has always been true that when employers shirked or avoided the duties of leadership, the rank and file employee craving leadership has found it elsewhere. If employers fail in their proper appreciation of fine workmanship the creative inspiration of the employee will find its expression elsewhere. But if employers are not found wanting, if the premium of justly expressed appreciation of skilled workmanship is not lacking, skilled work will be forthcoming. Times and industrial processes may change but human nature remains pretty much the same. It is to the advantage of all that industry be stabilized and that each individual find his place in the scheme of things. Pride in good work is not dead. The way must be found to solve the great cross puzzle of industrial life, and in that solution an ever growing system of apprentice training will have its place.

The American Society of Mechanical Engineers is shouldering a share in the responsibility for the problem. Its Committee on Education and Training for the Industries is actively at work getting detailed information of industrial-education courses wherever they exist all over the country. With this as a beginning they will endeavor to build an intelligent plan for the study of the subject and eventually to have something constructive to offer American industry in the solution of the pressing problem of securing skilled labor.

Science—The Destroyer?

BERTRAND RUSSEL records as the greatest problem of the future "the adjustment of mechanical organization to minister to individual freedom and happiness." His latest book, "Icarus or the Future of Science," takes up an important phase of the problem and presents a case against science, which he sums up in the following words: "Icarus having been taught to fly by his father, Daedalus, was destroyed by his rashness, and I fear that the same fate may overtake the population whom modern men of science have taught to fly."

In a review of this book in the *New York Times* for Sunday, March 30, Eugene S. Bagger points out that the trouble with Icarus was that his technical equipment was too much for his brain. "His modern counterpart, visible daily," says Mr. Bagger, "is the young man in the raccoon coat who drives a 60-hp. Rolls-Royce with a dozen cocktails inside him. That young man is a symbol of mankind, riding to destruction in the high-powered car of modern science while intoxicated with nationalism and a dozen other superstitions."

Modern industry is built upon the achievements of science. Its growth depends upon further scientific research and investigation. Science has alleviated disease, has furnished the conveniences for a broadened life—and this has brought happiness to modern people. It is true that science is also responsible for powerful engines of war and agents that may be for mankind's wholesale destruction. Therefore, there is demand for serious thought about the indictment that Mr. Russell brings against science as man's destroyer. It is well that the human race should face this problem cooly, without fear, with the firm resolve that science shall not be abused, for in its abuse lies the danger. If mechanical organization is to be adjusted to minister to individual freedom and happiness, leaders must arise who, from a thorough understanding of science and its benefits and a clear conception of what universal wellbeing means, may divert its uses into the right paths. The objection is made that leadership of this kind is not possible because of man's inability to increase the scope of his mind at the

same rate that science is expanding. Time only can answer this objection. One thing is certain, the ordinary political intelligence is not adequate for the control of scientific forces. If catastrophe is to be averted leaders must arise from the fields of science, industry, and economics, men with scientific training and practical experience, but men whose interest in the ultimate welfare of mankind has not been dulled. The present generation of engineers and engineering students should find its place in the sun.

Epochal Meetings

WHEN a Steinmetz meets a Rice and their joint genius results in great scientific advances we say that their first meeting was "epochal." In a different manner momentary contacts between sympathetic and complementary minds are daily affecting the course of world happenings, perhaps as much as the meetings of genius. Ambitious minds constantly seek the opportunity to talk with the sympathetic listener to give and gain knowledge.

Meetings of all professional organizations afford an opportunity for these interchanges of inspiration and for many "epochal" meetings as well. The Cleveland Spring Meeting, with its strong and diversified program is the immediate opportunity for members of the A.S.M.E. to renew their professional zeal, to fill the chinks of their minds with valuable information and to cultivate the sense of fellowship. It would be well if each one who attended went with the definite objective of making the gathering in Cleveland "epochal" in its effect on his engineering career.

British Specifications of the "Mechanical Engineer"

QUALIFICATIONS of the mechanical engineer and the education designed to give them were stated by Captain H. Riall Sankey, C.B., C.B.E., R.E., ret., Past-President of the Institution of Mechanical Engineers, in an address broadcasted in England on February 6, 1924. Captain Sankey, who is also a member of the A.S.M.E., is one of the outstanding mechanical engineers of the British Empire and his views on this subject are stimulating and inspiring.

Mechanical engineering, said Captain Sankey, is not a profession to be entered into lightly. It entails hard work, both physical and mental; there is great responsibility, and only those of considerable ability, continued determination, and honesty of purpose will succeed.

The qualifications of a mechanical engineer, on the attainment of which his education and training should be based, may be stated as follows:

The power of handling men and a knowledge of organization and administration
A mind trained to assimilate new ideas and to arrive at correct conclusions from given facts
A good stock of knowledge of mechanical matters
A knowledge of mathematics, physics, chemistry, and general engineering
A facility for consulting books of reference
An aptitude for making and reading drawings and making hand sketches
The power of putting ideas on paper in good intelligible English
A knowledge of the use of machine tools and other mechanical contrivances
A knowledge of at least one foreign language
A determination to do his work honestly and well
A willingness to take responsibility.

The education and training designed to give these qualifications can be divided into four parts:

1 A sound general education in which the literary subjects are just as important as the scientific.

2 A technical education to obtain a competent knowledge of those branches of science which form the basis of engineering, and especially their application to mechanical engineering.

3 A practical training to apply this knowledge to actual engineering conditions, both in the shops and the office.

4 Commercial and administrative experience.

Continuing, Captain Sankey spoke as follows:

It is a mistake to specialize too soon; in the early years the aim should be to get a broad general knowledge of men, materials, and processes as applied to all engineering. Specialization will come later, more or less automatically, according to aptitude and to the kind of mechanical engineering that circumstances may dictate.

It is very important that some knowledge of law, bookkeeping, costing, and administration generally, should be obtained, and that a precision in the use of words should be cultivated. These last remarks open up a very large subject at present not adequately dealt with in the education of the mechanical engineer. It is a good thing to join in the activities of other engineering students and learn to take part in discussions at meetings so as to acquire the art of speaking in public.

In conclusion, I would like to emphasize that the education of a mechanical engineer is never finished until he gives up work. Fresh knowledge must be obtained every day to keep abreast of the duties required of him. This is no hardship and, to my mind, is the charm of the entrancing career of a mechanical engineer.

Recent Developments in Aeronautics

IN AN address before the Waterbury Section of The American Society of Mechanical Engineers on February 21, 1924, Prof. Edward P. Warner, of the Massachusetts Institute of Technology, reviewed some interesting developments in aeronautics. Emphasizing the rapidity of airplane development, Professor Warner pointed out that while December 17, 1923, marked only the twentieth anniversary of the first heavier-than-air flight, speeds had risen from the twenty-five miles an hour of the first Wright biplane to the two hundred and forty-six miles an hour of the latest Navy racer. Progress also spells differentiation of function and military airplanes are now sharply specialized in the four classes of pursuit, observation, bombardment, and attack, while in commercial aircraft the types are just as sharply divided. Particularly interesting in this regard is the contrast between large machines such as the Vickers Vimy, used in non-stop flights across the Atlantic, and the small, low-powered sporting planes. One of these midget machines weighs only four hundred pounds, has an engine of twenty-four cubic inches displacement, equivalent to one cylinder of a Ford, and will fly a hundred miles to a gallon of gas. In naval aviation one of the newest developments of recent years is the introduction of the aircraft carriers such as the Langley, with a flat, uninterrupted deck the entire length of the ship on which land planes may alight with the ship either at rest or under way.

Speaking of the commercial operation of airplanes, Professor Warner pointed out that its development in Europe is considerable, and it is now possible to cover by air a distance of nearly 6000 miles from Moscow to a point in Africa, with the exception of 200 miles by rail. American aviation is well advanced, technically, but is very backward commercially, and requires urgently the support of the American people to take its rightful place in the economic world.

The Duty of Industry to Support Research

RESEARCH today is extending the boundaries of every field of human activity and thought, and, more effectively than ever, is directing industrial expansion into new channels and new territories. We are, for example, about to witness revolutionary changes in the preparation and use of fuel. Powdered coal has already established itself in engineering practice. Much progress has been made in low-temperature carbonization, with higher recoveries of chemical values and the production of artificial anthracite. The conversion of coal to liquid hydrocarbons through hydrogenation has been demonstrated on a commercial scale in Germany, though the figures on the balance sheet are doubtless still in red. The gas industry is destined to a great expansion, which will involve radically new methods. The industrial use of gas has scarcely begun, yet in Baltimore, within the last six years, more gas has been consumed than during the preceding century. Systems for the complete gasification of coal have been developed, and there are serious proposals for great gas works at the mines and the distribution of industrial gas through high-pressure mains.

Steam pressures in central stations have reached 500 lb., and pressures of 1200 and even 1500 lb. are cautiously being tried. They present problems in the behavior and strength of steel at high temperatures in contact with water and gases that can only be solved by intensive research. The gas turbine presents other

problems, which seem to be nearing a solution, but here, again, is more research required.

Decades of research have brought us to the point where we may soon expect oxygen, the supporter of combustion, to be as cheap by the ton as coal. That implies an impending revision of blast-furnace practice and of many operations in general metallurgy. It presents the possibility of the continuous gas producer and should raise the quality and heating power of industrial gas. It calls for new refractories.

Petroleum is about to be raised to a new and higher plane of usefulness and value, where it will serve as the starting point for the synthesis of whole series of organic compounds.

Biological chemistry is contributing new fermentation processes, which yield butyl and amyl alcohols, acetone, glycerine, and fats, and in its alliance with medicine is conquering some of the most terrible scourges of the human race.

In 1922 Bohr published The Theory of Spectra and Atomic Constitution. That, is seemingly far removed from industry and practical affairs. But Bohr's theory indicated that an unknown element should exist in zirconium-bearing minerals. In 1923 Coster and Hevesy, by means of X-ray analysis, found the element as predicted. It is named hafnium, in honor of Bohr's city, Copenhagen. That you may the better appreciate the potentialities of this discovery let me add that hafnium is estimated to represent 1/100,000th of the earth's crust and to be, therefore, more plentiful than lead, tin, and many other materials of commerce.

The French chemist Dumas writing to Pasteur concerning Lavoisier, the father of chemistry, said:

> **The art of experimentation leads from the first to the last link of the chain, without hesitation and without a blank, making successive use of Reason, which suggests an alternative, and of Experience, which decides on it, until, starting from a faint glimmer, the full blaze of light is reached.**

Our prosperity in the past has been largely based on cheap land and superabundant raw materials. Today our civilization has developed such complexity that we cannot hope to maintain our position except through the assistance which only science can afford. The laboratory has become a prime mover for the machinery of civilization, and the evidence that has been placed before you justifies the claim that there is a direct obligation upon industry to support research with the generosity of an enlightened self-interest, for Research is the Mother of Industry.—From a paper by Arthur D. Little read before a meeting of the Division of Engineering, National Research Council, New York, December 7, 1923.

British Empire Exhibition to have Palace of Engineering

THE British Empire Exhibition, Wembley, London, April to October, 1924, will show to the world the wealth of natural products and manufactures which the British Empire is able to put at the service of mankind. It will be a colossal shop window for the display of the products of the Home Country and the Dominions, Colonies and Overseas Dependencies, an effort of great magnitude but one worthy of the Empire it represents, embracing, as it does, a quarter of the known globe and a population of 450 millions.

One of the most interesting features of the Exhibition is the Palace of Engineering which has a floor space of over half a million square feet. (The total area of the grounds is more than 216 acres.) This is the largest building in the Exhibition and covers probably a larger area than any other ferro-concrete building in the world. It is twice the size of the machinery hall at the Franco-British Exhibition in 1908. There has been no attempt to surpass what has been done before. The building had to be its present size in order to contain the huge quantity of machinery which is on view and is an excellent illustration of the position to which engineering has grown in recent years.

To provide for the power which will be used for the Exhibition, a power station has been erected on the north side of the Palace of Engineering, of which it really forms a part. This station is a collection of exhibits representing the varied practice of many different manufacturers but coördinated to serve the useful purpose of supplying power for the Exhibition. The selection and layout have been made with extraordinary engineering skill and are worthy of high commendation.

The Palace of Industry, which is the second of the buildings in size, is also a ferro-concrete structure covering an area of nearly ten acres.

Doctor Klingenberg Visits Us

DR. G. KLINGENBERG, president of the Verein Deutscher Ingenieure, Deutscher Verband Technisch-wissenscahftlicher Verein and director of the Allgemeine Electricitaets Gesellschaft, accompanied by his wife, spent the month of April in this country acquainting himself with power developments in the United States. He visited plants in New York, Schenectady, Boston, Niagara Falls, Detroit, Pittsburgh and other cities and expressed satisfaction over the results of his trip.

At a meeting of the Metropolitan Section of the Society in New York City on March 25, Dr. Klingenberg made a short address outlining the information brought out in the "high-pressure" meeting of the V. D. I. recently.

A.S.M.E. Spring Meeting in Cleveland

THE A.S.M.E. Spring Meeting will be held in Cleveland, Ohio, from May 26 through May 29. The program, which appeared in the April 7 issue of the *A.S.M.E. News*, contains matter of interest to all mechanical engineers and the largest Spring Meeting attendance is expected.

The high lights of the technical program include the presentation by W. L. R. Emmet of a paper on the Mercury-Vapor Process and a session in which the American Society for Testing Materials is coöperating on the Properties of Materials at High Temperatures. There will be a joint session with the American Society of Refrigerating engineers who are also having their meeting in Cleveland at that time.

Headquarters have been set up at the Hotel Cleveland and those who plan to attend are encouraged to make their hotel reservations as early as possible.

The current issues of the *A.S.M.E. News* will give information about any changes or additions to the program.

Dr. Wilhelm Schmidt Dead

DR. WILHELM SCHMIDT, whose pioneer work relating to the art of steam superheating led to the development of the most widely used types of locomotive superheaters, died on February 16 at Bethel, near Bielefeldt, Germany, at the age of sixty-six.

Dr. Schmidt started his career as a locksmith, and it was entirely through coincidence that his great natural ability to correctly speculate on matters of physics and engineering came to the attention of prominent men who made it possible for him to educate himself and carry through the realization of his ideas. Schmidt, who in early years recognized the great importance of the superheating of steam for the economy of steam engines, spent the larger part of his life in fighting the prejudices that made learned engineers opposed to this practice, and to build up an organization which was finally able to overcome these prejudices and carry his ideas to commercial success. His best-known accomplishment was the creation of a practical locomotive superheater, but he also did much toward the practical superheating of steamships and stationary power plants.

Within the last ten years of his life he spent much effort and vast sums of money on the demonstration of practical ways and means to combine the thermal advantages of high superheat with the thermal advantages of relatively high steam pressures, which he termed "super pressures." While he did not live to see his inventions relating to steam super pressures widely exploited, he nevertheless had the satisfaction of having the engineering fraternity of his own country acknowledge the genius of his conceptions in this field. He had many unusual honors conferred upon him, among which was an honorary degree of Doctor of Engineering from one of the universities of his country.

Dr. W. H. Maw of "Engineering" Dies

THE death of William Henry Maw, LL.D., one of the founders and, up to the last, senior joint editor of our British contemporary, *Engineering*, at his home in Kensington, England, on March 19, 1924, has removed from the engineering and scientific world one of its most highly honored and deeply respected members. Dr. Maw possessed that rare combination of qualities, a truly scientific mind and a developed editorial sense. Since the establishment of *Engineering* in 1866 he was continuously one of its active editors, and up until within the past few years he had an independent practice as a consulting engineer, his work being largely in connection with engine and boiler construction and the design and arrangement of workshops and similar buildings.

Dr. Maw was born on December 6, 1838, at Scarborough. He received a private education and, as was the common practice of those days, became an apprentice to engineering at the locomotive works in Stratford when he was barely sixteen. Here his advancement was rapid. In less than five years he was appointed chief draftsman in the locomotive department. It was while working at Stratford that he first met Zerah Colburn and Henry Bessemer. Colburn, who had for some years been editor of *The Engineer*, proposed that they start another paper, and with the help of Bessemer and James Dredge, *Engineering* was established in 1866. In 1870 Mr. Colburn retired from his position on the paper and Mr. Maw was joined in the editorship by Mr. Dredge. After the death of Mr. Dredge in 1906, Dr. Maw continued as senior joint editor until the day of his death. The commanding influence of this paper is due in large part to the high standards which he set for it from the beginning and to his ceaseless vigor in keeping it up to the standards which he had set.

WILLIAM H. MAW

Dr. Maw's literary achievements other than those in *Engineering* consist of numerous papers and addresses delivered before scientific societies and a number of standard works of which he was joint author. His section of Mr. Colburn's book on locomotives, relating to valve gears, still remains practically a classic on the subject. In his work as a consulting engineer he took particular pleasure in arranging and laying out the printing works for several of the great daily and weekly newspapers of England, notably the *Daily Telegraph*, the *Standard*, the *Field*, the *Queen*, and others.

For many years Dr. Maw was an energetic and valuable worker for various technical institutions throughout the country. It is noteworthy that 59 years elapsed between his first presidential address in 1863, before the Civil and Mechanical Engineers' Society of which he was one of the founders, and his last, before the Institution of Civil Engineers in 1922. Perhaps the institution which profited most by Dr. Maw's work was the Institution of Mechanical Engineers, to which he was elected in 1873. He served as its vice-president and president, and for 30 years continuously on its Council. He did remarkable work for the British Engineering Standards Association and was a member of the Cleveland Institute of Engineers and the Royal Society of Arts.

For his work in astronomy Dr. Maw was almost as well known as for his work in engineering. He had observatories at his town house in Kensington and at his country seat at Outwood, Surrey, both of which were built to his own design. His most notable original research in astronomy was connected with double-star observations. He was one of the founders in 1890 of the British Astronomical Association and was a member of the Royal Astronomical Society since 1888, serving as its president for two years, 1905-1906. For many years he was a member of the Board of Visitors of the Greenwich Observatory and of the Joint Solar Eclipse Committee. He was a fellow of the Royal Geographical Society and of the Royal Microscopical Society.

Dr. Maw numbered many American scientific men among his personal friends. Back in the days when he was an apprentice in the locomotive works at Stratford he formed his first American acquaintanceships with visitors he used to show through the shops. For decades after that his editorial office was a mecca for distinguished American engineers who called to introduce themselves and to thank him for what he had done for the profession, but who remained and came again to enjoy the pleasure of his companionship. He was a most approachable man with a rare sense of humor and a deep appreciation for work well done, whether it was done by the professional or by the lowliest amateur.

In an autobiography to be published under the auspices of the A.S.M.E. this fall, Dr. John A. Brashear, Past-President of the Society, tells of meeting Dr. Maw in London in 1888 and subsequently. "I met no more delightful man in London than Mr. Maw," he says, and speaks of evenings spent in the house in Kensington where the observatory and 6-inch telescope became an additional bond in the growth of the friendship which existed between these two simple but unique characters.

Dr. Maw became a member of The American Society of Mechanical Engineers in 1913.

Thomas C. Mendenhall Dies

DR. THOMAS C. MENDENHALL, last member of the first faculty of Ohio State University, and chairman of the board of directors of the university, died on March 23 at his home in Ravenna, Ohio, at the age of eighty-two. Doctor Mendenhall's educational work was international, for he taught both in the East and the West. He served not only his mother institution, Ohio University, but spent several years at the Imperial University of Tokio, Japan, where he not only founded a laboratory of a western type, but also established an observatory, and made the beginnings of a governmental meteorological system. Dr. Mendenhall was one of the founders of the Tokio Seismological Society.

Returning to the United States, he developed a weather service in the state of Ohio and then served the Federal Government in its Signal Service and later in the Coast and Geodetic Survey. For five years he was president of Worcester Polytechnic Institute and for three years of Rose Polytechnic Institute. He was also at one time chairman of the Massachusetts State Highway Commission, and attained the distinction of being elected president of the American Association for the Advancement of Science. This latter honor came to him when he was still a young man and only half-way through the career which was destined to be so long and so active.

Engineering and Industrial Standardization

Standardization of Traffic Signals

THE A.E.S.C. has recently reported the completion of the personnel of the Sectional Committee for a Code on Colors for Traffic Signals and satisfactory progress in the preliminary stages of its work. Charles J. Bennett, former State Highway Commissioner of Connecticut, is Chairman of the Committee, which numbers 44 members who represent 33 different organizations. The American Association of State Highway Officials, the National Safety Council, and the U. S. Bureau of Standards are the Sponsor Bodies.

The Committee is naturally giving its first attention to the collecting of data and the study of certain related problems. To this end it has organized three sub-committees, as follows: (1) Visibility of Luminous and Non-Luminous Signals, Dr. O. A. Gage, of the Corning Glass Works, Chairman; (2) Present Practice for Highway Signals, David Van Schaack, of the Aetna Insurance Company, Chairman; and (3) Signboard and other Non-Luminous Highway Signals, David Beecroft, Directing Editor, The Class Journal Company, Chairman.

The work of these sub-committees has progressed far enough to make it perfectly evident that at least three fundamental questions related to the color of the signals must be faced squarely and answered: namely, those of, significance visibility, and relative contrast.

The three sub-committees have digested the information pertaining to the visibility of different colors and have reached the conclusion that the experience of the railroads dare not be disregarded by using more than the three colors of red, green, and yellow in primary traffic-control signals. They will shortly formulate recommendations as to just what meaning should be assigned to each of these colors and just what range in color vision shall be allowed to be called that color. In other words, how *orange* a red may be and still be called red, not yellow. They have agreed that all highway signals intended for automobilists to read, ought to employ the same color scheme.

Timely Pointers

Gage Steel Committee. Since January, 1920, the Gage Steel Committee, an informally organized Committee sponsored by the Ordnance Departments of the U. S. Army and Navy and the Bureau of Standards, has been steadily at work on the solution of three distinct problems: (1) To increase wear resistance; (2) to reduce dimensional changes on hardening; and (3) to eliminate length changes with time.

A meeting of this Committee was held at the Bureau of Standards in February, sixteen members representing gage manufacturers, steel makers, Army and Navy Ordnance Departments, technical societies, and the Bureau being present. It was agreed that the work had progressed sufficiently far to warrant practical service tests, and with this object in view the secretary was directed to present the work of the committee to the automotive industries to secure their coöperation. Such coöperation will make possible the rapid carrying out of service tests.

Safety Code for Elevators. The Sectional Committee on a Safety Code for Elevators and Escalators, which now numbers 33 representing 19 different groups, held a three-day session on March 25, 26, and 27. Previous to this meeting 300 sets of galley proofs of the revised draft of this safety code were mailed to that number of individuals and firms with the request that they give the Sectional Committee the benefit of their criticism and comment. It was because the replies to this request were so numerous that the Committee was obliged to add an extra day and night session to its original program of a two-day session.

Another meeting will be held within the next two months, after which the revised code will be issued in pamphlet form. It will be recalled that this safety code was originally printed by the A.S.M.E. in January, 1921.

American Screw-Thread Standards. After nearly six years of conscientious effort on the part of the members of the National Screw Thread Commission and the Sectional Committee on the Standardization and Unification of Screw Threads, the screw-thread practice of the United States has been completely systematized as far as bolts, machine screws, nuts, and commercially tapped holes, are concerned. This American Standard has received the approval of the American Engineering Standards Committee and is now available in pamphlet form.

Standardization of Weights. The practice of certifying partial sets of new weights which was inaugurated some time ago by the Bureau of Standards has saved considerable expense in making up sets of certified weights and is being taken advantage of without causing the Bureau undue trouble or work. It is gratifying to note that this practice does not seem to have reduced the quality of weights produced by American makers. The record during February is characteristic, though perhaps a trifle better than the average. One maker submitted 29 weights with no rejections, another 129, also with no rejections, while a third submitted 73, of which about 3 per cent were rejected.

Fire-Hose Coupling Threads. The A.E.S.C. has just completed a letter ballot approving as an American Standard the National Standard Fire-Hose Coupling Threads. This standard was developed originally by a committee of the National Fire Protection Association in 1905. Later the National Board of Fire Underwriters became interested in its promulgation.

Recently, however, it became evident that no real progress could be made in the adoption of this standard until it was definitely defined that thread gages could be made for the use of the field inspectors of this equipment, whether they be the chiefs of the fire departments or the chief engineers of the local water-works companies. In its new form this standard has the endorsement of the many organizations which approved it before, and it is now to be sponsored by the American Water Works Association, the N.B.F.U. and the A.S.M.E.

Pamphlet copies of this standard also are now available, together with descriptive pamphlets on Field Inspection of National Standard Fire-Hose Threads, and Production of National Standard Fire-Hose Threads.

Proposed Standards for Slotted Head Screws. Sub-Committee No. 3 on Slotted Head Products of the Sectional Committee on the Standardization of Bolt, Nut and Rivet Proportions has completed its tentative report, which covers the standard dimensions for the sizes of slotted heads for machine and wood screws. This material, consisting of eight tables supplemented by text and formulas, is now available in pamphlet form for general distribution. A copy of it will be mailed to any one who is willing to give the Committee the benefit of his criticism and comment.

Measurement of Thread Gages. Several fine-pitch thread gages were tested by the Bureau of Standards during the past month. In this connection it seems worth while to point out that there is no general agreement among manufacturers as to the contact pressure to be used in measuring thread gages by the three-wire method. In consequence, disputes frequently arise between the gage maker and user respecting pitch-diameter measurements. The gage maker is frequently allowed a tolerance of only 0.0002 in., while measurements recently made show that the reading over the wires on a 28-pitch thread gage may be decreased over 0.00015 in. when the contact pressure is increased from 2 to 5 lb.

Standards for Machined Fits in Interchangeable Manufacture. The Committee on Plain Limit Gages for General Engineering Work, a Sectional Committee organized under the procedure of the American Engineering Standards Committee, met in Washington on February 14th. Proof sheets of the Committee's report containing fundamental definitions and a classification of fits for machined parts were revised to bring them into complete harmony with the revised report of the National Screw Thread Commission, and two additional sub-committee reports were tentatively approved. The first revised report of the Committee will soon be

ready for submission to the sponsor society for approval and adoption, and for transmission to the A.E.S.C. for approval as a Tentative American Standard.

International Standards for Ball Bearings. Soon after the return of the American representative to the Zurich Conference, the Sectional Committee on the Standardization of Ball Bearings held a meeting in New York for the purpose of discussing the International Proposals which O. R. Wikander brought back with him. Believing, however, that they required more detailed study than could be conveniently given in a large group, the Committee referred them to the two technical groups known respectively as the S.A.E. Ball Bearing Division and the A.S.M.E. Ball Bearing Committee. The last-named group has met recently and has framed a set of recommendations to the Sectional Committee which have been mimeographed and are available for general distribution.

Aeronautical Safety Code. A meeting of the Sectional Committee for Aeronautical Safety Code sponsored by the Society of Automotive Engineers and the Bureau of Standards, was held in New York on April 8. At this meeting the following parts of the Code were discussed and ordered set in type and distributed for general criticism and comment: Introductory Part. Scope and Nomenclature; Part 1, Airplane Structure; Part 2, Power Plants; Part 6, Traffic Rules; Part 7, Qualifications for Pilots; Part 10, Parachutes.

At previous meetings of this Sectional Committee the Sub-Committees submitted the balance of the ten parts into which this safety code is divided. These parts are now available in pamphlet form and copies may be obtained on application to Dr. M. G. Lloyd, Bureau of Standards, Washington, D. C. They are: Part 3, Equipment, Maintenance and Operation of Airplanes; Part 4, Signals and Signaling Equipment; Part 5, Airdromes and Airways; Part 8, Balloons (Free and Captive); Part 9, Airships.

Standard Sizes of Shafting. After a thorough study of the situation as it affects sizes of transmission- and machinery-shafting stock extending over a number of years, the Sectional Committee on the Standardization of Shafting, Cloyd M. Chapman, Chairman, has submitted its final report to the A.S.M.E., its sponsor. This report has already been approved and adopted by the Council of the A.S.M.E. for the Society and has been transmitted by it to the A.E.S.C. for approval as a Tentative American Standard.

Pipe Flanges and Fittings. Two new sub-groups have been formed under Sub-Committee No. 1 on Cast Iron Flanges and Flanged Fittings. These groups are charged with the responsibility of preparing the preliminary drafts of standards for (*a*) low-pressure (under 100 lb. per sq. in.) cast-iron flanges and flanged fittings, and (*b*) flange and flanged-fitting standards for ammonia refrigerating systems. The personnel of both sub-groups have been agreed on and the first held two meetings in April. The second is planning to hold a meeting early in May.

Carriage Bolts. One of the three projects discussed during the Washington Conference of February 19 called by the Department of Commerce, Division of Simplified Practice, at the request of the National Association of Farm Equipment Manufacturers, was the standardization of round unslotted heads for bolts. The representatives of the Sectional Committee on Bolt, Nut and Rivet Proportions presented the set of standard dimensions prepared by its Sub-Committee No. 5, and the N.A.F.E.M. presented the recommendations of its standards committee. After a detailed study of both proposals the conference group approved the Sectional Committee's report with slight modifications and additions. Sub-Committee No. 5 has completed the revision of its report and it is now available in proof form.

Plow Bolts. A second project covered by the Washington Conference in February was the standardization of plow bolts. In this case the Sectional Committee had no standards to offer. Accordingly the proposals of the N.A.F.E.M. were carefully reviewed in conference and were approved with slight changes and additions. Copies of these revised dimensions also are available to those interested.

Small Rivets. Standard dimensions for small steel rivets—$^{7}/_{16}$ in. in diameter and under—are proposed by the report of Sub-Committee No. 1 of the Sectional Committee on the Standardization of Bolt, Nut and Rivet Proportions. This report is now being distributed in proof form for criticism and comment.

Standard Rules for Guarding Belts, Pulleys, Gears, Etc. The guarding of all types of mechanical power-transmission apparatus is one of the essential precautions of all industrial concerns employing machinery of any kind. It was for this reason that the A.S.M.E. took an active part in the development of the national Safety Code for Mechanical Power-Transmission Apparatus.

This Code has now received the approval of the A.E.S.C. and the designation of American Standard. It is printed in the convenient pocket size, $5^{1}/_{4} \times 7^{3}/_{4}$ in., and has been so favorably received that the first printing is almost exhausted.

Minimum Live-Load Requirements. The Building Code Committee of the Department of Commerce has just completed its tentative report entitled Minimum Live Load Requirements for Use in Design of Buildings. The three parts into which this proposal is divided cover (*a*) Introduction: Brief description of the organization and procedure of the Building Code Committee; (*b*) Recommended Limitations for Safe Loads as the Basis of Design—these are briefly stated in the form of recommendations suitable for municipal adoption; and (*c*) Appendix: A statement of the data and reasoning upon which the recommendations in Part (*b*) are based.

Discussion and criticism of these recommendations are solicited. Copies of the report in printed pamphlet form are available upon application to Dr. Ira H. Woolson, Chairman, care of the Department of Commerce, Washington, D. C.

Proposed Standard Smoke Ordinance

A TENTATIVE DRAFT of a Standard Smoke Abatement Ordinance has been prepared by a joint committee made up of representatives of the American Society of Heating and Ventilating Engineers, the Stoker Manufacturers' Association, the American Civic Association, and the Fuels Division of the A.S.M.E.

The Committee is desirous of obtaining helpful criticism and suggestions about this ordinance, which should be mailed to the Chairman, Dr. O. P. Hood, Bureau of Mines, Washington, D. C.

The personnel of the Committee is as follows: Dr. O. P. Hood, Chairman, and Henry Kreisinger, representing the Fuels Division A.S.M.E.; P. J. Dougherty, representing the A.S.H. & V.E.; Lloyd R. Stowe, representing the S.M.A.; Everett L. Millard, representing the A.C.A.; and Osborn Monnett and Harry B. Meller, members at large.

PROPOSED STANDARD SMOKE ORDINANCE

AN ORDINANCE regulating the emission of smoke from any chimney, smokestack or other source within the corporate limits of the City of....., creating a Bureau of Smoke Regulation, constituting its personnel and prescribing penalties for the violation of the provisions thereof.

SEC. 1. *Be it ordained and enacted* by the City of....., in Council assembled, and it is hereby ordained and enacted by the authority of the same, that there is created a Bureau of Smoke Regulation, the chief of which shall be known as.....(1).....

The Mayor shall appoint a.....(1)..... at a salary not to exceed.....per annum. The person so appointed shall be an engineer qualified by training and experience in the theory and practice of the construction and operation of steam boilers and furnaces, and also in the theory and practice of smoke abatement and prevention.

The.....(2).....may, upon the recommendation of the .....(1)....., appoint .....(3)..... at a salary not to exceed.....per annum. The person or persons so appointed shall be engineers, qualified by training and experience in the theory and practice of the construction and operation of steam boilers and furnaces and the firing of furnaces.

The.....(2)..... may appoint such other inspectors and employees in the Bureau of Smoke Regulation as may be necessary for the proper performance of the work of the said Bureau at such salaries as may be fixed by .....(4).....

The Mayor shall appoint an Advisory Board of..... engi-

neers, who shall act as advisers on engineering questions to the .....(1)..... Bureau of Smoke Regulation. The Advisory Board shall act as a board of appeals as provided in Section 4 of this ordinance. The members shall serve without pay, except when acting as a board of appeals, when they shall receive the sum of .....each per meeting.

SEC. 2. "Persons" shall be considered as referring to all individuals, partnerships, or associations other than corporations.

"Corporations" shall be considered as including all bodies corporate, joint stock companies or associations, domestic and foreign, their lessees, assignees, trustees, receivers and other successors in interest having any of the powers or privileges of corporation not possessed by individuals, partnerships, or unincorporated associations.

"Chart," shall be considered as referring to the Ringlemann Smoke Chart as published and used by the United States Bureau of Mines.

"Stack" shall be defined as including chimneys, smokestacks, structures and openings of any kind whatsoever, capable of emitting smoke. Smokestacks on locomotive roundhouses shall be deemed parts of locomotives beneath them for the time being.

"Advisory Board" shall be considered as referring to the Board of Engineers appointed by the Mayor to act as advisers on engineering questions to the Bureau Chief, Bureau of Smoke Regulation of the City.

SEC. 3. The production or emission within the City of smoke, the density or shade of which is equal to or greater than Number three (3) of the Ringlemann Chart, from any stack, except that of a locomotive or steamboat, for a period or for periods aggregating two (2) minutes or more in any period of fifteen (15) minutes, and the emission of such smoke from any locomotive or steamboat for a period or for periods aggregating one (1) minute or more in any period of eight (8) minutes, is hereby prohibited.

SEC. 4. No person or corporation shall construct, install, reconstruct, alter or repair any furnace, boiler furnace, stack or other apparatus connected with stack, unless he or it shall make application in writing to the Bureau of Smoke Regulation on the form furnished by the said bureau, duly sworn to before a notary public, or any person authorized to administer oaths, for a permit for such construction, installation, reconstruction, alteration or repair, and in and by such application shall give the plans and specifications, showing the style and dimensions of the furnace, boiler furnace, stack or other apparatus connected with a stack intended to be used, a description of the building or part thereof in which such furnace, boiler furnace, or other apparatus is located, including the means provided for regulating the temperature of such building or part thereof and ventilating the same, and generally all provisions made for preventing smoke, together with a statement of the kind of fuel proposed to be used and of the operating requirements to be made of the furnace or furnaces referred to therein, and unless such application shall be passed upon by the Bureau of Smoke Regulation, and approved in writing and a permit issued as hereinafter provided; *provided*, however, that minor or emergency repairs which do not increase the capacity of such furnace, or which do not involve any substantial alteration in such furnace, boiler furnace, stack or other apparatus, and which do not involve any alteration in the method or efficiency of smoke prevention, may be made without a permit.

Any application shall be approved or rejected within ten (10) days after it is filed in the office of the Bureau of Smoke Regulation.

Upon the approval of any application, a copy of which shall be left on file in the office of the Bureau of Smoke Regulation, and upon the payment of the fees hereinafter provided, the Bureau of Smoke Regulation shall issue a permit for the construction, installation, reconstruction, alteration or repair of such furnace, boiler furnace, stack or other apparatus.

In the event that any such application is rejected by the .....(1)....., Bureau of Smoke Regulation, the applicant has the right to appeal from his decision to the Advisory Board. Such appeal shall be made in writing to the .....(1)....., Bureau of Smoke Regulation, who shall call a special meeting of the Advisory Board within three (3) days for the consideration of the matter. If a majority of the members of the Advisory Board present shall be of the opinion that the application calls for such construction, installation, reconstruction, alteration or repair of furnace, boiler furnace, stack or other apparatus, that there will not under reasonable conditions of operation be produced or emitted from the stack connected therewith such smoke as is herein prohibited, the decision of the .....(1)....., Bureau of Smoke Regulation, shall be reversed and the finding of the Advisory Board shall be binding upon the .....(1)....., Bureau of Smoke Regulation; otherwise the same shall be confirmed. In which latter case the fees to the Advisory Board are to be paid by appellant, who shall first give bond or make other deposit of funds for the amount of the fees provided for in Section 1 of this ordinance.

SEC. 5. It shall be unlawful for any engineer, contractor, or other person or corporation to do the work of constructing, installing, reconstructing, altering or repairing any furnace, boiler furnace, stack or other apparatus connected with stack, unless the person or corporation for whom such construction, installation, reconstruction, alteration or repair is being made has proper authority, in the form of a permit from the Bureau of Smoke Regulation, for such work.

SEC. 6. For examination of an application for a permit for any such construction, installation, reconstruction, alteration or repair, the Bureau of Smoke Regulation shall collect at the time of issuing such permit, for the use of the City, a fee of .....

The issue and delivery by the Bureau of Smoke Regulation of any such permit shall not be held to exempt the person or corporation to whom the permit has been issued or delivered or who is in possession of the same, or whose application has been approved, from prosecution on account of the production or emission of smoke hereby prohibited.

SEC. 7. The .....(1)....., Bureau of Smoke Regulation, shall keep in the office of the Bureau of Smoke Regulation all applications made, and a complete record thereof as well as of all permits issued. He shall also keep a record of all smoke observations on all stacks and generally of the work done by the Bureau of Smoke Regulation. All such records shall be open for inspection by the public at all reasonable times. He shall in all matters pertaining to the enforcement of the provisions of this ordinance report direct to .....

SEC. 8. The .....(1)....., Bureau of Smoke Regulation, his deputies and inspectors shall have the right to enter in the performance of their duties at all reasonable hours, all premises from which smoke is being emitted or has been emitted, and any person who shall, after proper identification, deny admittance to such person or persons or interfere with him or them in the performance of his or their duties shall be liable to a fine not exceeding.....or undergo an imprisonment in the county jail or workhouse of not more than.....or both, at the discretion of the committing magistrate or alderman.

SEC. 9. If any person or corporation shall violate any one or more of the prohibitions or requirements of this ordinance, the .....(1)....., Bureau of Smoke Regulation, shall enter suit before any police magistrate or alderman of the City of....., and upon conviction such person or corporation shall be subject to a fine or penalty not exceeding .....for each and every violation thereof, and each day's violation shall constitute a separate offense; or undergo an imprisonment in the county jail or workhouse of not more than..... or both, at the discretion of the committing magistrate or alderman.

SEC. 10. (*a*) Each power boiler with more than 1500 square feet of heating surface, using coal as fuel, shall be provided with a mechanical stoker or other device or attachment approved by the Bureau of Smoke Regulation.

Heating surface shall be construed to mean all boiler surfaces in contact with hot gases.

(*b*) The minimum distance between dead plate and boiler shell for horizontal return tubular boilers shall be not less than the following, according to diameter of boiler:

Diameter of boiler, inches	Distance from dead plate to shell, inches
48 and less	30
54	32
60	34
66	34
72	36
78	38
84	38

In most cases it is desirable to have more than this minimum.

(*c*) Where it is proposed to use oil or powdered coal as fuel for horizontal return tubular boilers, the height of the boiler shell above the ashpit shall be not less than 60 inches; in most cases more is desirable.

(*d*) All hand-fired furnaces for stationary boilers carrying more than[1] .....pounds steam pressure shall be provided with steam-air jets or other approved method of admitting auxiliary air above the grates.

If steam-air jets are used, there shall be one such jet for each 250 square feet of heating surface or fraction thereof, and the minimum number of steam-air jets shall be three.

(*e*) Boilers carrying not to exceed[1].....pounds steam pressure shall be provided with openings to admit auxiliary air above the fuel bed, having a free air opening of not less than 3 square inches for each square foot of grate surface.

(*f*) All return tubular boiler settings, in addition to steam-air jets and auxiliary air openings, shall have such gas-mixing arches, piers or other devices as are acceptable to the Bureau of Smoke Regulation.

(*g*) Full extension furnaces shall be used on all stationary hand-fired vertical fire-tube boilers. The arch of the extension furnace must extend 4 feet behind the grate.

(*h*) Each hand-fired water-tube boiler of the highly inclined or vertical type shall have full extension furnace with an arch extending at least 4 feet back of the grate and firebrick piers or other acceptable construction installed.

(*i*) Each chain-grate stoker shall have an ignition arch with minimum length equal to.....of the length of active grate.

(NOTE: In the Illinois district it is the judgment of chain-grate engineers that this minimum should be $^3/_5$ and that in no case should the length of arch be less than 5 feet. Further east $^2/_3$ may be sufficient.)

(*j*) Side inclined and front overfeed stokers installed under vertically baffled boilers may be set with flush front provided the minimum distance from grate surface to heating surface is $7^1/_2$ feet. If minimum distance is less than $7^1/_2$ feet, a full extension furnace, with arch extending 2 feet back of the grate, shall be used.

(*k*) Where side inclined and front overfeed stokers are installed under horizontal return tubular boilers, full extension settings shall be used.

(*l*) Portable boilers of the vertical or locomotive type shall use "smokeless" fuel, unless such boilers are equipped with approved smoke-preventing devices which will insure "smokeless" operation under normal working conditions.

(*m*) Low-pressure heating boilers carrying not to exceed[1] ..... pounds steam pressure and rated 2000 square feet or more of steam radiation or 3000 square feet or more of water radiation, shall be of a satisfactory "smokeless" type and capable of reducing the amount of smoke produced so as not to exceed the limit set by Section 3.

(*n*) Low-pressure heating boilers carrying not to exceed[2] ..... pounds steam pressure and rated below 2000 square feet of steam radiation or 3000 square feet of water radiation and hot-air furnaces with more than 9 square feet of grate surface, if not of a satisfactory "smokeless" type, shall burn only "smokeless" fuel.

(*o*) All low-pressure boilers shall be provided with openings to admit auxiliary air above the fuel bed, having a free air opening of not less than 3 square inches for each square foot of grate surface.

(*p*) The projected grate area of any boiler using coal as fuel shall be not less than $1/60$ of the heating surface where stokers are used and $1/45$ of the heating surface in hand-fired furnaces.

(*q*) The area of the breeching in units not exceeding 1000 horsepower shall be $1/8$ of the grate area.

(*r*) Unless the height of the flue or stack is greater than 150 feet, the breeching must not drop below the horizontal at any point from boiler to stack.

(*s*) The unrestricted area through the damper on any water-tube boiler shall be not less than $1/8$ of the grate area, and for horizontal-return tubular, internally fired Scotch marine or Continental type boilers, shall be not less than 25 per cent in excess of the combined inside area of tubes.

(*t*) All power and heating plants of over 25 horsepower capacity shall be equipped with stack of sufficient height to give a minimum of 0.25 inch draft over the fire in the furnace under normal working conditions.

(*u*) Kent's formula, H.P. = $3.33\ E\sqrt{H}$, may be used to determine the size of the stack. For each right-angle bend in the breeching 10 feet shall be added to the height so determined.

H.P. = rated boiler horsepower
= square feet of heating surface ÷ 10 for power boilers
= square feet of direct radiation (rated capacity) ÷ 100 for steam-heating boilers
= square feet of direct radiation (rated capacity) ÷ 150 for water-heating boilers

E = effective area of stack in square feet
= $A - 0.6\sqrt{A}$, when A = actual area in square feet

$\sqrt{E} + 4$ in. = inside dimensions of a square stack

Diameter of
$E + 4$ in. = inside diameter of a round stack

H = height of stack in feet.

(*v*) The height of the stack shall be at least 30 times its inside dimension when the height does not exceed 65 feet.

(*w*) No stack to which a "smokeless" boiler (2000 square feet or more capacity steam radiation or 3000 square feet or more capacity water radiation) is attached shall be less than 50 feet high above the center of the breeching connection to the stack.

(*x*) The inside walls of the stack shall be smoke-tight, vertical, free from offsets, constrictions or enlargements, and shall have no openings between the breeching and the top of the stack.

(*y*) The top of the stack shall extend above or be far enough away from any nearby building to avoid downdrafts.

(*z*) The minimum setting heights of boilers shall be those recommended by the Stoker Manufacturers' Association and the Boiler Manufacturers Association in 1922.

SEC. 11. Any Ordinance or part of Ordinance conflicting with the provisions of this Ordinance shall be, and the same is, hereby repealed, so far as the same affects this Ordinance.

(1) May be "Bureau Chief," "Superintendent," "Smoke Commissioner," or "Chief Smoke Inspector."
(2) The Mayor or other authority designated by him or by the Council.
(3) May be "Deputy" or "Assistant" with any of the designations in (1).
(4) Usually the Council.

Emmet Mercury-Vapor Process

(*Continued from page 240*)

In Hartford, where oil is burned and measured and where steam flow and feed are both measured, it has been estimated that if the steam produced were used effectively, the fuel rate would be about 12,000 B.t.u. per kw-hr. This is with only 1200 kw. load, a single-wheel turbine of only about 60 per cent efficiency, and with only 22 lb. mercury pressure.

For the purpose of giving an idea of possibilities in existing stations, the cases of three large plants—among the best in the country—operating for the month of January, 1924, have been considered. The following table shows the conditions in these plants and the gain in net output which would have resulted if the same fuel had been burned under mercury boilers, with the same auxiliary and flue-gas conditions; it being assumed that the mercury turbines with generators are 70 per cent efficient and that a mercury pressure of 70 lb. gage is used.

	Plant 1	Plant 2	Plant 3
Capacity in kilowatts	180,000	50,000	100,000
Economizers	No	No	Yes
Steam pressure, lb. per sq. in.	219	286	235
Superheat, deg. fahr.	217	245	200
Load factor, per cent	57	50	50
B.t.u. in fuel per kw-hr.	19,850	19,700	18,250
Gain in output if fuel had been burned under mercury boilers, per cent	65	58	51

These estimates do not admit of much error. The combustion conditions would be the same in both cases and no additional auxiliary load would be occasioned by the change. There would be some difference in banking and starting since the mercury equipment would not generally be designed for heavy overloading at peaks as is common with steam boilers.

If in such cases the conditions described above as desirable were used instead of the flue-gas and feed-heating arrangements employed in these stations, the fuel efficiency would be considerably better.

With the same steam turbines and condensers in each of these cases plant capacity could be more than doubled by providing full mercury-boiler equipment. From this fact it may be inferred that the process affords great advantages in the matter of investment as well as of operation.

THE MERCURY SUPPLY

The demand for mercury has always been strictly limited and it is probably not safe to predict positively the consequences of a greatly increased demand. The cost is governed largely by the richness of ore. Ore of various grades exists in many places and it only now pays to work the best of it. A well-informed mercury-mine operator has estimated that a maintained price of $2 per lb. would call forth from known sources in the United States enough mercury, if used as we expect, to correspond in plant capacity to the largest yearly output of General Electric turbines. Several other experienced persons have expressed opinions generally agreeing with such a view. Unworked deposits are known in Alaska, South America, New Zealand, and elsewhere, and a rise of price will undoubtedly bring much more to light. It is thought, therefore, that we need not slack our efforts for the present through fear of a shortage of mercury.

OTHER SUBSTANCES

Mr. Parkman Coffin of the General Electric Research Laboratory has made for the author a search for substances which might be used in this general way instead of mercury. Some substances of considerable stability and desirable thermodynamic properties have been found, but none of the possibilities, with the exception of sulphur, have stood continued boiling under pressure without gradual change and deterioration. Among the materials tried were diphenyl, diphenyl ether, and benzophenone. Means might be devised by which sulphur could be used as a thermodynamic fluid. The principal objections to it are that it attacks steel at the temperatures needed, and that it is viscous and a very poor heat conductor even at the temperature of the highest-pressure steam which might be used to take heat from it in a condenser. Certain aluminum-iron alloys might make practicable containers, and the rates of condensation to the temperature of 1200-lb. steam have been measured and are not entirely prohibitive. It has peculiar thermodynamic characteristics and is obviously much less desirable for such a purpose than mercury. These studies have inclined the author to the idea that nothing other than mercury is ever likely to be used for such a purpose.

PLANS FOR THE FUTURE

As soon as certain boiler experiments now in progress are satisfactorily completed, it is proposed to build a new boiler of a different type for the existing Hartford installation. This boiler we propose to adapt for a pressure of 70 lb. gage, the design pressure of the present boiler being 35 lb. gage. We also intend to build a new three-stage turbine instead of the one-stage turbine now used. When these changes are made it is hoped that this installation will be representative of types which can be repeated indefinitely on a large scale and with such resultant economies as have been outlined in this paper.

[1] This will vary according to location. As a matter of fact, the minimum pressure at which steam-air jets are really effective is about 60 pounds.
[2] May vary in different states. In Pennsylvania, for example, the dividing line between high pressure and low pressure is placed at 15 pounds.

Library Notes and Book Reviews

THE Library is a cooperative activity of the A.I.E.E., the A.S.C.E., the A.I.M.E. and the A.S.M.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

COKE AND ITS USES. By E. W. L. Nicol. D. Van Nostrand Co., New York, 1924. Cloth, 7 × 10 in., 134 pp., illus., tables, $5.

The book, of English origin, is intended to promote the use of coke as fuel for steam raising and for domestic purposes, as a means of promoting efficiency and of preventing smoke. Methods and apparatus are described, and comparisons between coal and coke are given.

CURRENT ECONOMIC AFFAIRS. By Walter Renton Ingalls. G. H. Merlin Co., York, Pa. 1924. Cloth, 6 × 9 in., 211 pp., $2.50.

This collection of addresses and papers is, the author says, "the first serious attempt to study the distribution of wealth among the classes of people in the United States." The economic situation since the World War is discussed and certain prophecies made concerning future conditions. Some current fallacies are exposed. Many of the papers have previously appeared in *Mining and Metallurgy*.

ELECTRIC ARC AND OXY-ACETYLENE WELDING. By E. Arthur Atkins. Isaac Pitman & Sons, London and New York, 1923. Cloth, 5 × 7 in., 316 pp., illus., diagrams, tables, $2.50.

A very complete manual on methods, equipment and materials, and on the welding of various metals. Gives the results of many tests and experiments.

DIE ELEKTROSTAHLÖFEN. By E. Fr. Russ. R. Oldenbourg, Munich and Berlin, 1924. Paper, 6 × 10 in., 471 pp., illus., diagrams, $3.30.

This volume on the electric steel furnace is intended to give the steel maker a thorough, practical account of the use of the electric current for melting steel. It therefore assumes no technical knowledge of electrical engineering on the part of the reader, theoretical points are discussed as briefly as possible and attention is concentrated on the practical questions and requirements which directly interest the metallurgist. The book commences with a statement of basic electrical principles, which is followed by a discussion of the various methods of heating by electricity. The various types of furnaces that have been tested in practice are then described and their advantages explained. The concluding section treats of the parts of furnaces; electrodes, regulating and safety apparatus, measuring devices, etc.

FERRARIS' DIOPTRIC INSTRUMENTS, an Elementary Exposition of Gauss' Theory and its Application. By Galileo Ferraris, translated by Oscar Faber from F. Lippich's German translation. D. Van Nostrand Co., New York, 1920. Cloth, 6 × 9 in., 214 pp., $3.

Owing to the abstruse mathematical language in which Gauss clothed his additions to our knowledge of optics, the practical value of his theory has been appreciated very slowly. Ferraris' treatise, published over forty years ago, gives an elementary geometrical development of the theory and applies it to dioptric instruments. Mr. Faber has now translated Ferraris' work into the English language at the suggestion of some English manufacturers of optical wares. His translation, made from the German translation of 1879, has been improved by the correction of errors and by the omission of matter which is no longer important.

FOIBLES AND FALLACIES OF SCIENCE. By Daniel W. Hering. D. Van Nostrand Co., New York, 1924. Cloth, 5 × 8 in., 294 pp., illus., portraits, $2.50.

Dr. Hering writes, in popular fashion, of astrology, the transmutation of metals, perpetual motion, divination, hoaxes, prophecies, and other frauds and fallacies of pseudo-science, many of which have reappeared from time to time.

GASWORKS RECORDERS, THEIR CONSTRUCTION AND USES. By Leonard A. Levy. Benn Brothers, London; D. Van Nostrand Co., New York, 1922. Cloth, 7 × 10 in., 246 pp., illus., diagrams, $10.

Describes the pressure recorders, vacuum gages, pyrometers, specific-gravity apparatus, calorimeters, gas analysers, volume recorders, densimeters, and depth gages used in gas works, and explains their use and maintenance. Intended for students as well as for engineers.

HENDRICKS COMMERCIAL REGISTER OF THE UNITED STATES. Thirty-Second annual edition. 1924. S. E. Hendricks Co., New York, 1923. Cloth, 8 × 12 in., 2402 pp., $15.

A very full directory of manufacturers and dealers, compiled with special reference to the requirements of those engaged in engineering, mining, railroading, building and kindred industries. The commodities are listed under some 17,000 headings. An index of trade names and an alphabetical list of firms are included.

HOT BULB OIL ENGINES AND SUITABLE VESSELS. By Walter Pollock. D. Van Nostrand Co., New York, 1919. Cloth, 6 × 9 in., 429 pp., illus., diagrams, $10.

The object of this book is to call attention to the new possibilities that have been introduced in the design of vessels by the adoption of the low-compression oil engine for marine purposes. It explains the engine and calls attention to its advantages, discusses the merits of the various designs and gives examples of its application to vessels for various purposes. The book is for owners and operators, rather than for designers, so the discussion of the details of design is omitted.

LIFE OF SIR WILLIAM CROOKES. By E. E. Fournier D'Albe. D. Appleton & Co., New York, 1924. Cloth, 6 × 9 in., 413 pp., portrait, $7.50.

Sir William Crookes led a long life of activity in many lines. He was an early expert in photography, he founded the *Chemical News* and edited it until his death, he discovered thallium and invented the radiometer. He was an early scientific investigator of spiritualism. His technical activities were many and varied. His biographer presents an interesting life of the man as his friends knew him, largely through extracts from his letters and other writings.

LOW TEMPERATURE CARBONISATION. By S. N. Wellington and W. R. Cooper. Charles Griffin & Co., London; J. B. Lippincott Co., Philadelphia, 1924. Cloth, 6 × 9 in., 238 pp., diagrams, tables, $9.50.

While much has been written in periodicals on this subject, the authors of this work feel that it has not hitherto been treated adequately in book form. The present volume discusses theoretical aspects of the problem, describes the systems that have been tried commercially and presents unpublished results of research. The volume concludes with a consideration of the power aspects of low-temperature carbonization. An appendix gives abstracts of the important British patents.

MEASUREMENT OF STEADY AND FLUCTUATING TEMPERATURES. By R. Royds. D. Van Nostrand Co., New York, 1921. Cloth, 6 × 9 in., 162 pp., illus., diagrams, $4.

This book gives a concise account of modern methods for measuring both steady and fluctuating temperatures and indicates their applications in industry. Mercury thermometers, electrical ther-

mometers and pyrometers, radiation and optical pyrometers and other types are described. There are chapters on calibration, on the measurement of the mean temperature of thin metal walls, such as engine-cylinder walls and boiler tubes, and on the measurement of rapidly fluctuating temperatures.

PLANNED CONTROL IN MANUFACTURING. By William O. Lichter. Ronald Press Co., New York, 1924. Cloth, 6 × 9 in., 329 pp., $5.

This volume sets forth the basic principles of planned control which are applicable to any business and which make it possible to obtain the full benefit of standardization through job analysis. The author has not treated the subject exhaustively but has discussed intensively the points that experience has shown to be of primary importance. The book treats of the installation and maintenance of control methods and the selection and training of the control staff, describes the relation of these methods to purchasing and cost accounting, and applies planned control in detail to a small plant, as a practical example.

PULVERISED FUEL. By W. Francis Goodrich. Charles Griffin & Co., London; J. B. Lippincott Co., Philadelphia, 1924. Cloth, 5 × 8 in., 215 pp., illus., diagrams, tables, $4.50.

Mr. Goodrich reviews the origin and history of pulverized fuel; describes practice in the United States, in France and in Great Britain; considers the design, equipment, and operation of plants; discusses the fuel suitable for use in pulverized form; and gives his conclusions as to the future use of pulverized fuel. He has produced a concise, practical handbook, based on personal investigation in the countries named.

WEALTH AND INCOME OF THE AMERICAN PEOPLE. By Walter R. Ingalls. Second edition. G. H. Merlin Co., York, Pa., 1923. Cloth, 6 × 9 in., 372 pp., tables, $3.50.

In the present book Dr. Ingalls aims to explain the nature of the wealth of the United States and to examine comparatively the positions before and after the war. He discusses the amount of the income that we as a people derive from the use of our wealth and our work and the distribution that we make of it; and finally he discusses the economic consequences of the war to us and the way in which the ravages of the war may be repaired. In the new edition corrections have been made, some later data added to the tables, and three new chapters introduced.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. 1923–24. Thomas Publishing Co., New York, 1924. Cloth, 9 × 12 in., 4300 pp., $15.

Little change in general character is to be expected in a directory that has gone through fourteen editions, and the new edition of "Thomas" follows the lines of preceding ones. It is, however, enlarged by over a hundred pages. The Register lists and indexes manufacturers and first hands in all lines, making it easy to locate sources of supply for any commodity. An alphabetical list of forms, an index to trade names and brands, a directory of banks boards of trade and other organizations, and a directory of trade papers are also among the features included. Capital ratings are given for all firms. It is, the publishers claim, the largest directory for buyers.

Production of Heavy Forgings

(Continued from page 247)

in the forgings. It would appear that in order to make a good forging it is necessary to have a good ingot, i.e., one free from blowholes, contraction cavities, and sonims (solid non-metallic impurities). Modern steel plants are fully capable of producing such ingots with the sacrifice, of course, of a certain part at the top of the ingot which is cropped off in order to remove the pipe. The dendritic structure of the ingot usually persists in the forging and experiments made at the Bethlehem Steel Co. have shown that as far as the change in the grain structure of the metal is concerned, it is immaterial whether the ingot is reduced in the ratio of four to one or twenty to one. Numerous tests have shown, however, that the presence of dendrites in a forging otherwise properly produced does not mean any weakness of the forging within the factors of safety usually imposed on these kinds of structures.

Mechanical Engineering of Management in the Metal-Working Trades

(Continued from page 274)

study a jig was made in which two pieces were butted together and drilled through the junction, the drill cutting half in each piece. Not only was a better job secured, but the time for two pieces was 20 min., or a gain of 37 min. per piece. This great saving, however, was the least important feature of the change. The slotter was set free for other work, and the total production of the shop was increased by making a greater supply of material available for operations subsequent to the cutting of the grooves.

In a preceding paragraph an instance in simplification in machine methods by a change in design of product was mentioned. The problem in this case was to achieve a very large increase in volume of output. The original method of making the plates in question was to saw them to length from steel flats, and then plane them all over. Both were relatively slow operations. In the new method the flats were first planed to width, and then cut off in a shear fitted with a spacing table. They were then gang-milled on one face and both ends in a milling machine fitted with a fixture which could be loaded at one end while the other end was under the milling cutters. The final operation was to grind to thickness on the unfinished face in a vertical surface grinder. The production was more than quadrupled.

The point of the preceding paragraph is not the decrease in cost of manufacture, desirable as it was, through the substitution of cheaper methods; it is rather the fact that the shop was confronted with a sudden necessity of greatly increasing its output. While this could have been done by increasing the equipment used under the old method, the cost would have been prohibitive, even if room could have been found for it in an already overcrowded shop. Furthermore the cost and labor of scheduling and supervising the additional men and machines would have added a considerable burden to an already overburdened production department. The problem for the mechanical engineer in this case was clear cut, and it was one that could only be solved by a radical change in method, even though it involved changes in equipment.

In dealing with the equipment it will be found that standardization is a powerful ally to production. Machines that are supposed to do the same work should be capable of the same standard of performance. As an instance, two makes of machine were supposed to be equally capable of doing the same work. Piece rates were set for one, and applied to the other. The men on the first set of machines were easily able to accomplish their task, while those on the second set consistently failed. The operators were interchanged, and still the second lot of machines proved inferior at production. An intensive time study then revealed that a few minor differences in the machines were responsible. A second or two more for chucking work, a fraction of a second longer for shifting gears, a longer reach for the controller handle, and such items, all small in themselves, made a cumulative total that materially cut down the output for the day. The trifling cost of making the necessary changes paid large dividends in satisfied workmen and increased output.

Neglect of such small details as shape of cutting tools and their proper hardening have an astounding effect on production. The time for completing jobs on lathes has been held by the operators, time and again, to be too low. Investigation has revealed that they were using tools not ground or heat-treated in accordance with the standard used in setting the time. This indicates the necessity of central toolrooms for standard grinding and heat treating the tools, and the determination by the engineer of what these standards shall be.

The author realizes that what has been set forth presents nothing that is new in machine-shop practice. Yet it has been brought home to him many times that the self-evident things are frequently the most neglected ones, and that before any real management can be attempted there is much that must be done in the way of good old-fashioned mechanical engineering. Any other procedure will result in a makeshift, and lead to trouble and discredit for the man responsible. If he has succeeded in making this point plain, his object has been accomplished.